**House Tax Policy Committee**
**Public Testimony**
**Presented by John Kennedy, Vice President for Operations of Internet2**


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Thank you Mr. Chairman and members of this Committee, I appreciate the opportunity to appear before you today and share with you what Internet2 is all about and what we do. I will close by highlighting Senate Bill 926 and ask for your support of this proposed legislation.

## INTERNET2

### ABOUT INTERNET2:

- Internet2 is a not for profit 501(c)(3) organization and is a technology based research and development enterprise.
- Internet2 is the United State's premier national research and education networking consortium and has its headquarters in Ann Arbor, Michigan.
- Internet2 was established in 1996 by leading U.S. research universities and is today led by 208 universities – including University of Michigan, Michigan State University, Michigan Technological University, Wayne State University, and Western Michigan University.

### ACTIVITIES OF INTERNET2:

- Internet2 and its member universities work in partnership with government and industry to develop advanced Internet technology, accelerating the creation of a next-generation Internet.
- Internet2 has deployed a high-performance nationwide network known as the Abilene network, that connects 240 of its university, corporate, and government members, as well as 35 state education networks such as MichNet in Michigan. More than 46,000 K-20 institutions – schools, museums and libraries – are connected across the United States.
- This very advanced network also connects to 70 international research networks deployed by organizations like Internet2 in other countries.

- In addition, close to 70 corporations from diverse industries – such as Michigan's Ford Motor Company, Steelcase, and VoEx – are active collaborators and important contributors within the Internet2 community.

- Internet2 networks today connect users at speeds of at least 100 megabits per second, 100 times faster than a typical home broadband or DSL services.

- Many schools are now upgrading their own networks to provide even faster speeds. By providing this speed and capacity, students, faculty and researchers are able to routinely use advanced Internet technologies to create global classrooms, virtual operating rooms, and research labs that extend under the oceans and to the tops of mountains in ways not previously possible.

- Today, physicians can teach hands-on operating procedures to surgical trainees over the network, students and researchers can view and control remote microscopes and telescopes, and master musicians can instruct student violinists over great distances.

**PAST, PRESENT, & FUTURE OF INTERNET2:**

- Internet2 was originally launched as a project of the higher education not for profit organization, Educause, in Washington, DC.

- Headquarters were moved to Ann Arbor in 1998 for access to highly qualified staff and network resources.

- As the organization was scaling up in numbers of members, projects and staff over the next couple of years, consideration was being given to where to locate the headquarters going forward.

- We were very pleased to receive a Core Communities Fund Grant from the MEDC in 2002 which led us to form the Michigan Information Technology Center Foundation, another not for profit, and leverage the grant support to build out excellent work space for Internet2, provide space for the Merit Network organization and develop a technologically state of the art conference center in Ann Arbor.

- Today, Internet2 has about sixty staff in Ann Arbor, ten in Washington, DC and twenty-one located on Internet2 member campuses around the country.

- Internet2 is embarking on significant work to upgrade its network to support the requirements for technology based research and development for education in the United States which will lead to exciting new projects and additional staff requirements.

- Knowing that we can build on the successes of the past there is much more to be discovered and achieved. Internet2 has continued to grow and expand since moving to Ann Arbor and is poised for future growth and investment.

**SENATE BILL 926:**

- This bill clarifies the Michigan Strategic Fund Act by extending the property tax exemption to a non-profit research and development enterprise that subleases and occupies real property.

- Under Section 6 of the Michigan Strategic Fund Act (PA 270 of 1984, MCL 125.2004 to 125.2086) tax exemptions are granted to certain nonprofit research and development enterprises that receive or have received at least $1,000,000.00 of State funding.

- The Michigan Strategic Fund Act only applies the exemption from property taxes to personal property that is owned and used or real property which is owned and occupied.

- Internet2, a 501(c)(3) organization that engages in technology research and development activities, currently subleases space.

- The Michigan Strategic Fund Act also applies an exemption only to research and development enterprises that receive or have received financial aid directly from the Act.

- However, it does not take into consideration that in certain instances financial aid or assistance is passed through by a third party which is how Internet2 received funding from the Core Community Grant.

**CLOSING REMARKS:**

When the Michigan Strategic Fund Act was originally passed it did not take into consideration the fundamental change regarding research and development activities. The cost of conducting research and development has and continues to increase. As a result, many private companies and non-profit organizations have opted to conduct joint research through organization and operation of R&D partnerships commonly referred to as "consortiums".

In these situations the actual R&D activity of the consortium is for the most part performed at multiple locations but coordinated from a central location such as the case for Internet2. Therefore, a Michigan non-profit R&D enterprise that subleases and occupies real property and received financial benefit of state funds ends up having to pay property taxes.

SB 926 rectifies this oversight and ensures that state funds are being used for the appropriate purpose. Internet2 asks for the House Tax Policy Committee to support and pass this proposed legislation. On behalf of Internet2 and its "consortium" members, I thank you for your time and would welcome you to visit our facility to learn more about Internet2. We appreciate the bi-partisan support of SB 926 and also thank the co-sponsors of this bill, Senator Cassis and Senator Brater.

Again, thank you for your consideration and I would be happy at this time to answer any questions.

INTERNET2

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* Denotes Collaboration Site

Technology
MIT

TechnologyReview

# 10 Emerging Technologies

**EACH YEAR,** *Technology Review* identifies 10 technologies that are worth keeping an eye on. This year's list spans a broad range of disciplines, from life sciences to nanotechnology to the Internet, but the technologies have one thing in common: they will soon have a significant impact on business, medicine, or culture.

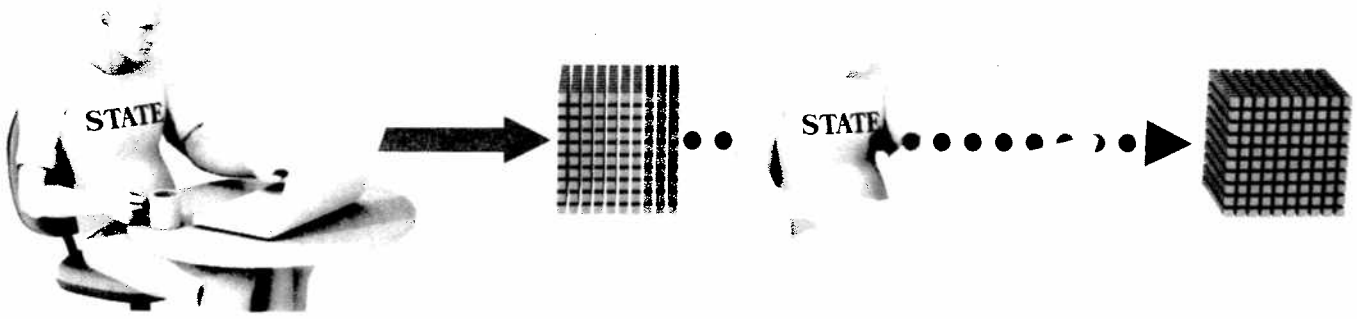
INTERNET SECURITY

## Universal Authentication

Leading the development of a privacy-protecting online ID system, Scott Cantor is hoping for a safer Internet.

**IF YOU'RE LIKE MOST PEOPLE, YOU'VE** established multiple user IDs and passwords on the Internet—for your employer or school, your e-mail accounts, online retailers, banks, and so forth. It's cumbersome and confusing, slowing down online interactions if only because it's so easy to forget the plethora of passwords. Worse, the diversity of authentication systems increases the chances that somewhere, your privacy will be compromised, or your identity will be stolen.

SECURITY WITH PRIVACY: Shibboleth software could create a far more trustworthy Internet by allowing a one-step login that carries through to many online organizations, confirming identity but preserving privacy. In this example, a student logs in to his university's site, then clicks through to a second university. Shibboleth confirms that the person is a student but doesn't give his name.




BRYAN CHRISTIE DESIGN

The balkanization of today's online identity-verifying systems is a big part of the Internet's fraud and security crisis. As Kim Cameron, Microsoft's architect of identity and access, puts it in his blog, "If we do nothing, we will face rapidly proliferating episodes of theft and deception that will cumulatively erode public trust in the Internet." Finding ways to bolster that trust is critically important to preserving the Internet as a useful, thriving medium, argues David D. Clark, an MIT computer scientist and the Internet's one-time chief protocol architect.

Scott Cantor, a senior systems developer at Ohio State University, thinks the answer may lie in Web "authentication systems" that allow users to hop securely from one site to another after signing on just once. Such systems could protect both users' privacy and the online businesses and other institutions that offer Web-based services.

Cantor led the technical development of Shibboleth, an open-standard authentication system used by universities and the research community, and his current project is to expand its reach. He has worked, not only to make the system function smoothly, but also to build bridges between it and parallel corporate efforts. "Scott is the rock star of the group," says Steven Carmody, an IT architect at Brown University who manages a Shibboleth project for Internet2, an Ann Arbor, MI–based research consortium that develops advanced Internet technologies for research laboratories and universities. "Scott's work has greatly simplified the management of these Internet-based relationships, while ensuring the required security and level of assurance for each transaction."

Shibboleth acts not only as an authentication system but also—counterintuitively—as a guardian of privacy. Say a student at Ohio State wishes to access Brown's online library. Ohio State securely holds her identifying information—name, age, campus affiliations, and so forth. She enters her user ID and password into a page on Ohio State's website. But when she clicks through to Brown, Shibboleth takes over. It delivers only the identifying information Brown really needs to know: the user is a registered Ohio State student.

While some U.S. universities have been using Shibboleth since 2003, adoption of the system grew rapidly in 2005. It's now used at 500-plus sites worldwide, including educational systems in Australia, Belgium, England, Finland, Denmark, Germany, Switzerland, and the Netherlands; even institutions in China are signing on. Also in late 2005, Internet2 announced Shibboleth's interoperability with a Microsoft security infrastructure called the Active Directory Federation Service.

Critically, the system is moving into the private sector, too. The science and medical division of research publishing conglomerate Reed Elsevier has begun granting university-based subscribers access to its online resources through Shibboleth, rather than requiring separate, Elsevier-specific logins. And Cantor has forged ties with the Liberty Alliance, a consortium of more than 150 companies and other institutions dedicated to creating shared identity and authentication systems.

With Cantor's help, the alliance, which includes companies such as AOL, Bank of America, IBM, and Fidelity Investments, is basing the design of its authentication systems on a common standard known as SAML. The alliance, Cantor says, was "wrestling with lots of the same hard questions that we were, and we were starting to play in the same kind of territories. Now there is a common foundation....we're trying to make it ubiquitous." With technical barriers overcome, the companies can now roll out systems as their business needs dictate.

*Universal Authentication*

| Researcher | Project |
|---|---|
| **Stefan Brands** *McGill University* | Cryptology, identity management, and authentication technologies |
| **Kim Cameron** *Microsoft, Redmond, WA* | "InfoCard" system to manage and employ a range of digital identity information |
| **Robert Morgan** *University of Washington* | "Person registry" that gathers identity data from source systems; scalable authentication infrastructure |
| **Tony Nadalin** *IBM, Armonk, NY* | Personal-identity software platform |

Of course, Cantor is not the only researcher, nor Shibboleth the only technology, in the field of Internet authentication. In 1999, for instance, Microsoft launched its Passport system, which let Windows users access any participating website using their e-mail addresses and passwords. Passport, however, encountered a range of security and privacy problems.

But thanks to the efforts of the Shibboleth team and the Liberty Alliance, Web surfers could start accessing multiple sites with a single login in the next year or so, as companies begin rolling out interoperable authentication systems.

**DAVID TALBOT**


www.internet2.edu

Forbes.com

# Consortium Builds Next-Generation Net

by David M. Ewalt

NEW YORK - The next generation of Internet networks isn't being dreamed up at Bill Gates' mountain retreat, pondered inside a corporate boardroom or sketched out in a basement research lab. It's already been built by a consortium that includes 207 universities, along with private and public research labs and government agencies. It's called Internet2, and it works like a test kitchen for tomorrow's networking innovations.

Internet2 is a nonprofit organization, founded in 1996 for the purpose of developing advanced networking technologies. It serves as an information clearing house, facilitating the exchange of research between members and allowing them to co-develop new bits of hardware and software.

"For a lot of these organizations, having a way to work with leading edge networks gives them an ability to sort of live in the future," says Internet2 Chief Executive Officer Doug Van Houweling. "If you really want to test what can be done, we provide an opportunity to do that."

Douglas Van Houweling
INTERNET2 President and CEO

Instrumental in that mission is Abilene, the consortium's private network. The most advanced research and education network in the United States, it connects member institutions at a rate of 10 gigabits per second, roughly 20,000 times faster than a typical home broadband connection. Four million users--mostly students, researchers and professors--use it to share information and test high-bandwidth applications that just couldn't run over the commercial internet.

Some of these applications are ones you might already use, like videoconferencing. But Abilene's users have such a high-quality connection that they don't have to deal with the shakes, jitters, slowness and errors common in existing commercial products, which opens up all kinds of new uses. Miami's New World Symphony uses Abilene to teach music classes to students. The connection provides enough clarity that it sounds like the student and teacher are in the same room, allowing instructors to identify wrong notes with the certainty that it isn't just a bad connection.

It's not just students taking advantage of Abilene's big pipes. About 60 corporations count themselves as members of Internet2, including tech giants Cisco Systems (nasdaq: CSCO), IBM (nyse: IBM), Microsoft (nasdaq: MSFT) and MCI (nasdaq: MCIP). "We actually provide a vantage point for our corporate members to see what advanced networks will look like, what they could do if they were working in a really high-bandwidth environment," says Van Houweling.

Juniper Networks (nasdaq: JNPR) counts Internet2 as both a client and a partner. A member since 2000, Juniper provided the high-performance 10-gigabit routers which hold Abilene together. Now they're using that powerful backbone to understand the demands of future computer users and test equipment for eventual commercial release.

Networks like Abilene are different from existing consumer networks. On today's Internet, traffic flows in millions of small streams, consisting mostly of simple communications like e-mail, text-based Web pages and instant messages. But on Abilene, information travels through a few hundred extremely large rivers in the form of high-bandwidth applications and complex academic systems. This puts different stresses on hardware and provides a unique test bed for products under development.

"We beta-test things on the Abilene network," says John Jameson, director of research education markets for Juniper. "It gives us a chance to bake our equipment in networks with large bandwidth requirements and allows us to stay on the cutting edge for all kinds of pipes. If these guys weren't building high performance networks we'd be at a loss."

Juniper is currently connecting an engineering lab in Sunnyvale, Calif. to the Abilene network, installing routers that are completely surrounded by monitoring equipment so they can play with their configuration and see how that affects traffic flow. "This is something that you can't really recreate in a test lab, and telecom carriers can't be putting monitors in the middle of their networks," says Jameson. This monitoring opportunity will help them develop products that can handle the high-bandwidth requirements of tomorrow's networks.

"When downloading movies over the Internet becomes common, there will be bigger flows of information than

ever before, and we'll have had years of experience handling it," he says.

Indeed, the proliferation of broadband applications like movies and video are what will drive deployment and adoption of next-generation networks like Abilene. But that's not expected to occur for several years.

But Internet2 isn't just about fast networks. The consortium has also made progress developing innovative software and services. "We're helping corporations experiment with and develop compatible ways of managing privacy and security" says Van Houweling.

One application, called Shibboleth, is a piece of open source software that enables users to share restricted online resources. Without the software, if a college or business wanted to subscribe to some kind of online database, they'd have to create hundreds or thousands of accounts, one for each individual user. That's a huge administrative burden, and particularly complicated in schools where new students are enrolling and old ones are graduating. But Shibboleth handles all the identification and authentication of users in between the school and the database, thus reducing the complexity of management and protecting the privacy of individual users. Pennsylvania State University is using the program to allow its students to access music download service Napster to give them a legal alternative to file sharing.

Development of the software was supported with funding from several public and private universities and the National Science Foundation. It's a partnership that might have been hard to come by if Internet2 wasn't around to serve as fertile ground for networking innovation.

"There aren't a lot of places which invite people with ideas across the full range to come together and talk about what makes sense for the future," says Van Houweling. "We want to make sure we help fill the vacuum that was left when the bloom went off the Internet rose."

There was a period when there were thousands of startups trying all kinds of things, Van Houweling notes, but now many of them are gone, and the remaining big corporations can't spend as much on research and development.

Internet2 helps fill that void. "We think that we're a highly effective way for corporations to come together, look at what's needed and jointly participate in building the technology that we're all going to need in the future."

Newsweek

Enterprise


PHOTOGRAPH COURTESY OF NEW WORLD SYMPHONY, MIAMI

Composer Aaron Kernis addresses an audience in Miami Beach from a remote location via Internet2

# Virtual Verdi

## Miami's New World Symphony is pioneering the use of Internet2 for performances across continents.

**BY ARIAN CAMPO-FLORES**

As he prepared for a high-stakes audition, bass player Matthew Way yearned for some guidance. But his old teacher Timothy Cobb, of the Metropolitan Opera, was in New York. And Way was 1,300 miles south, at the New World Symphony (NWS) in Miami Beach. Luckily for him, technology came to the rescue. One day in February, NWS brought Way and Cobb together with a next-generation videoconference, using Internet2—an advanced research network 1,000 times faster than regular broadband. With that speed and bandwidth, Way and Cobb could interact in real time, with DVD-quality video and sound that allowed them to pick up the subtlest musical nuances. Before an array of tech gear, Way performed a solo from Verdi's "Otello." Cobb, who was at Columbia University in Manhattan, appeared on a plasma TV on the wall. "Make it a little sadder," said Cobb, who demonstrated by playing a snippet on his own bass. Way tried again. "Much better," said Cobb.

So it goes at NWS, where high-tech wizardry meets classical music. An orchestral academy that's home to about 90 postgraduate fellows like Way, NWS has pioneered the use of Internet2 for musical learning and performance across continents. In 2000, NWS became the first orchestral institution to join the Internet2 consortium—a group of more than 300 universities, government agencies and corporations. But NWS is just getting started, says Michael Tilson Thomas, who founded the academy in 1987 and is also the music director of the San Francisco Symphony. Internet2 will be integrated into NWS's new music lab and performance space, due to be unveiled in 2010.

Internet2 has been around since the 1990s. It runs on the same fiber-optic network that carries regular Internet traffic. But the Internet2 backbone is physically separate. "Think of it as a private highway running in parallel with the public highway," says Laurie Burns, an Internet2 executive. "It's smoother, wider and banked better." Most of the time, Internet2 is used by researchers shipping vast amounts of data. But the network also functions as a testing ground for groups like NWS. Old videoconferencing and satellite technologies just aren't good enough because of hazy transmission and long delays.

NWS has high hopes for its new building. All the practice rooms will be wired for Internet2. In the performance space, huge video screens will link the audience with ensembles elsewhere. Tilson Thomas is toying with the idea of a "distributed performance," in which he'd simultaneously conduct different musicians in different cities. New World Symphony, indeed. ■

The Philadelphia Inquirer

THURSDAY, SEPTEMBER 22, 2005 Business WWW.PHILLY.COM

# A 'revolution' on the way - Making the Internet Wicked Fast

By Akweli Parker
INQUIRER STAFF WRITER

The audience watched closely and listened as Northwestern University student Anna Burden's fingers danced across the fingerboard of her cello, delivering first a Bach prelude, then a more up-tempo bluegrass piece.

Burden was in Chicago. Her audience was at the Wyndham Hotel in Philadelphia, participating in a demonstration of high-definition videoconferencing that is one of many applications being explored by members of the "Internet2" consortium.

"It's an amazing revolution" in music instruction, said Northwestern professor and renowned cellist Hans Jensen, appearing live from Chicago in HD alongside Burden. "This technology, I think, is phenomenal."

Jensen said he had used Internet2 technology to teach aspiring musicians remotely at universities scattered all over the country.

Internet2 members are brainstorming on policy and technology this week in Philadelphia, where the group is holding its fall meeting. It ends today.

Internet2 is a consortium of universities, government researchers, and corporate sponsors and affiliates who are working to develop high-quality, high-speed uses for the next generation of the Internet. Among the 206 universities in the consortium are the University of Pennsylvania, which is the host of this week's conference; Temple; Drexel; and Pennsylvania State.

One recurring theme at the conference: high-definition video over the Internet.

High-definition video comes in many flavors and protocols, but they all share this: They look fantastic.

In its purest form, HD video hogs lots of space on whatever fiber or cable is carrying the signal to your viewing screen–too much space to be practical for most broadband connections.

But the mini-concert by Burden was delivered over a one-megabit-per-second connection–slower than the cable-modem and DSL service available to many consumers for $30 to $45 a month. It was made possible by a video-compression scheme called MPEG-4.

LAURENCE KESTERSON / Inquirer Suburban Staff

**LifeSize Communications representatives Murina Fareed and Michael Kenoyer** talk about the high-definition, transatlantic-capable conferencing system made by their Austin, Texas company.

The technology was not perfect: Burden's image "pixelated," or turned blocky, when the system could not keep pace with her rapid bow strokes. And subtle color mismatches cued the viewer that this was not commercial TV.

The conferencing system's maker, LifeSize Communications of Austin, Texas, said those imperfections would not be present in the compact high-definition camera and telephone set-up going on sale in about a month. And the more bandwidth available–that is, the higher the transmission speed–the better the quality will be, according to the company.

One of the systems, consisting of a Frisbee-shaped telephone pad, a cylindrical high-definition camera, and a briefcase-size processor, costs $12,000. That is a reasonable price, said LifeSize spokeswoman Munira Fareed, for a system that allows companies to hold transatlantic conference calls in lieu of overseas travel.

"The issue is productivity," she said.

Meanwhile, Internet2 members are using a variety of methods to hold videoconferences in normal video resolution and to transfer huge libraries of research data that would become

LAURENCE KESTERSON / Inquirer Suburban Staff

**Northwestern University's Larry Amiot in Philadelphia (left) participates in a** demonstration of high-definition videoconferencing. He talks to Anna Burden and Hans Jensen (on the monitor) at the Chicago school.

### Internet2

Internet2 is a consortium that is developing advanced, high-speed uses for tomorrow's Internet.

**Members**: 206 universities, including Drexel, Penn, Penn State and Temple. Among the dozens of corporate/affiliate members are Comcast Cable and Children's Hospital of Philadelphia.

**Network speed**: Goal of providing 100 megabits per second to each connected desktop - 16 times faster than the fastest residential speeds currently offered by Comcast locally.

**Sample uses:**

- Astronomers in the U.S. mainland access observatories on a Hawaiian mountaintop.
- Doctors use virtual reality to diagnose patients from afar.
- Meteorologists link supercomputers with radar stations to provide better forecasts.

hopelessly logjammed on the public Internet used by most of the world.

The network used by Internet2 members aims to provide speeds of 100 megabits to each desktop connected to it, far faster than residential connections available today. Researchers are using it for a variety of purposes, such as connecting U.S. mainland astronomers with telescopes in Hawaii, and linking supercomputers with radar stations to improve the accuracy of weather forecasts.

Last night, conference host Penn was to connect University of Delaware students with Tlingit weaving artists at the University of Alaska and faculty from Cairo University in Egypt, while attendees in Philadelphia witnessed the interaction.

Internet2 officials say that like the original Internet, which also was developed by university and government researchers, Internet2's dramatically higher speeds and widespread use of video will someday become part of everyday life for the general public.

Fareed, for instance, said LifeSize was well aware of the Ojo, a consumer video phone made by Trevose-based Worldgate Communications Inc. and being sold by Motorola Inc.

"When we see products like that, it's actually gratifying," she said, "because it means we're getting closer to wide acceptance."

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INFORMATION TECHNOLOGY

# Not the Internet You Know

## An ambitious experiment could point the way to tomorrow's academic network

BY VINCENT KIERNAN

THE NEXT TIME you get testy waiting for a Web page or a digitized song to download to your computer, be glad that you are not Harvey B. Newman. Slow networks cause him far bigger headaches.

Mr. Newman, a professor of physics at the California Institute of Technology, needs to send huge files across the Internet to Caltech from the CERN high-energy-physics laboratory in Switzerland. The files contain data from particle-physics experiments, in which Mr. Newman and his colleagues search for evidence of particular subatomic particles.

Before long, he says, physicists will be seeking to move as much as 10 petabytes of information—or 500 times the amount of data contained in the Library of Congress—every year.

Understandably, he needs a fast network. "I want to avoid a complete logjam," he says. Conventional networks, shared by many institutions, frequently offer only a fraction of the necessary capacity, he says.

Help may be on the way. Networking researchers are preparing to start a nationwide series of experiments designed to point the way for a new approach to high-speed networking in academe, that could allow researchers to move large blocks of data quickly and easily. The result would be a faster, better academic arm of the Internet than Internet2's existing network, which is called Abilene. If the experiments, and others like them, are successful, the technology is likely to trickle down to consumer-oriented segments of the Internet, including the lines that serve homes and offices.

**"Right now, the network is a big black box. We put bits in one end and hope they come out the other end when we need it."**

Some networking experts in academe see the project, Hybrid Optical and Packet Infrastructure Testbed, or HOPI, as the blueprint for the next Internet. The project is being led by Internet2, whose Abilene network is now nearly a decade old and is scheduled to go out of operation within two years. That network provides a high-speed connection to more than 200 colleges and universities.

In the short term, the new network will merge Internet2's network with the National LambdaRail, a new fiber-optic network assembled for colleges' use (*The Chronicle*, July 9, 2004). Researchers will try to develop and test methods by which LambdaRail could automatically pick up some of the load on Abilene, such as when demand on Abilene surges because of massive transfers of data by scholars.

That kind of flexible interaction between computer networks could result in revolutionary improvements in performance. But it is not a simple matter because Abilene and LambdaRail use very different technologies.

### MASSIVE CAPACITY

Improving high-speed networks is more important than ever, as scientists' appetite for bandwidth is expected to grow ever more voracious.

"Big science these days is often turning into e-science," says Mark Johnson, chief technology officer for MCNC Grid Computing & Networking Services, in Research Triangle Park, N.C., which operates the North Carolina Research and Education Network. Last month Internet2 selected the network to play a key role in HOPI, providing support for the development of its software.

Internet2 develops and deploys advanced network applications and technologies, accelerating the creation of tomorrow's Internet.

As a research and development consortium led by U.S. universities, working in partnership with government and industry, Internet2 is transforming the way we work, learn and communicate.

# making the future real

**The Internet2 community is leading in the development of tomorrow's global Internet.** Through sustained investment and involvement, more than 300 Internet2 member organizations are:

**Building and extending technology** for the foundation for the future global Internet.

**Testing and deploying solutions** that enable advanced network applications and privacy-preserving online authentication.

**Developing and enhancing tools** that improve the performance of today's advanced networks.

**Collaborating** to further research and education through the use of advanced networking.

**www.internet2.edu**

INTERNET2

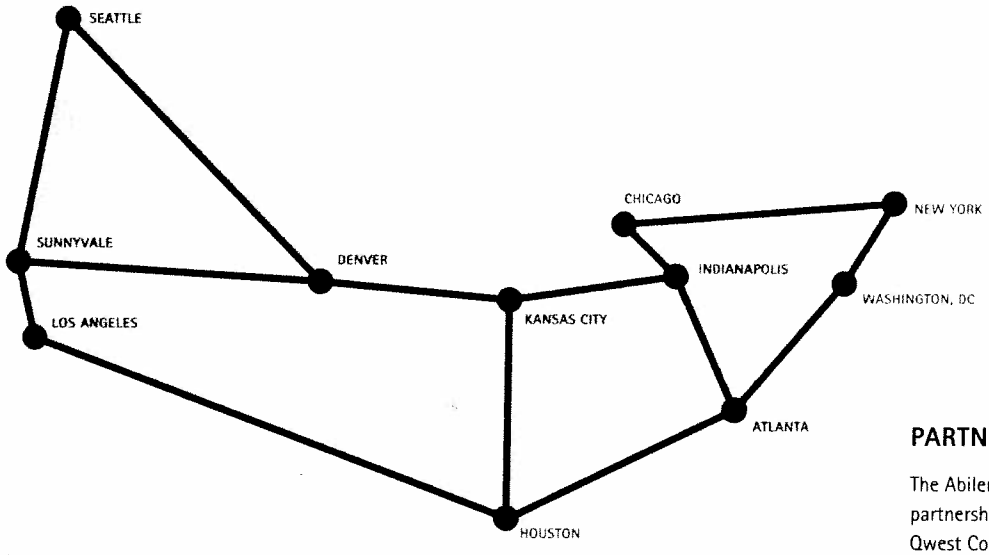
Images provided by (from left to right) the Scientific Computing and Imaging Institute, University of Utah; Megaconference; Gemini Observatory/Association of Universities for Research in Astronomy

# Abilene Network

Abilene

abilene.internet2.edu

The Abilene Network is an Internet2 high-performance backbone network that enables the development of advanced Internet applications and the deployment of leading-edge network services by Internet2 universities and research laboratories across the country. Created by the Internet2 community, Abilene connects regional network aggregation points—known as gigaPoPs—to provide advanced network capabilities to over 230 Internet2 university, corporate, and affiliate member institutions in all 50 states, the District of Columbia, and Puerto Rico. The current network is an OC-192c (10 Gbps) backbone employing optical transport technology and advanced high-performance routers.




**Abilene Network Design**

OC-192c

## PARTNERSHIPS

The Abilene Network is a partnership of Internet2, Qwest Communications, Nortel Networks, Juniper Networks, and Indiana University.



## Abilene Goals

The goals of the Abilene Network are to provide an advanced backbone in support of:

- Cutting-edge applications developed using innovative, experimental techniques and requiring high-performance network services not available on existing commercial networks.
- The deployment and testing of advanced services, including multicast, IPv6, measurement, and security, which are generally not possible on the commodity Internet.
- Connectivity to other research and education networks throughout the world, including the U.S. federal research networks, thus enabling the international research community to collaborate in new ways.
- Access for researchers to a rich set of network characterization data collected in a high-performance networking environment supporting new and innovative applications.

## ADVANCED SERVICES AND CAPABILITIES

Advanced Internet services are an important aspect of the Abilene Network, and include:

- Multicast
- Native IPv6 Support
- Measurement
- Security
- Raw HDTV Streaming – 1.5 Gbps
- Bulk Data Transfer
- Interactive Collaboration
- Grid Computing

## Abilene Community

The Abilene community includes three general levels of participation:

- **Primary Participants** – Internet2 members, including research universities and collaborating federal and corporate research laboratories located in the U.S.
- **Sponsored Participants** – Collaborating partners of Internet2 university members (e.g., small laboratories, museums, clinical research centers) requiring access to advanced networking.
- **Sponsored Educational Group Participants (SEGP)** – Aggregations of state education networks connecting the K-12 community, baccalaureate and community college networks, and libraries.

## Global Research Interconnectivity

The Abilene Network provides connectivity for participating institutions to over 40 other research and education networks, both within the United States and internationally. Abilene also serves as an International Transit Network so that two international peers can transit Abilene for interconnectivity when required.

## The Abilene Observatory

*http://abilene.internet2.edu/observatory*

The Abilene Observatory supports the network research and advanced network engineering communities through the collaborative sharing of the vast amounts of network performance information gathered within the Abilene Network and the facilitation of innovative network experiments deep within the core of a national backbone network. The Observatory effort has two essential components:

- An accessible, correlated archive of data collected by the Abilene project team using dedicated measurement servers in each of the Abilene router nodes; and
- The support of affiliated research projects through the placement of experimental servers and other measurement equipment in these nodes.

## Advanced Network Applications

The development of advanced applications is an essential component of Internet2. The Abilene Network provides a platform for the deployment of such applications.

### Remote Media Immersion

*http://imsc.usc.edu/rmi/*

Tremendous network resources are required to capture, stream, and render the high-resolution, big-screen digital video and high-fidelity, multichannel audio needed to create a seamless, teleimmersive presence. Researchers at the NSF-funded University of Southern California Integrated Media Systems Center are using Remote Media Immersion (RMI), which combines several breakthrough Internet technologies, as a test bed to deliver immersive experiences over the Abilene Network. Their experiments have yielded the error-free transmission of multiple synchronized data streams with sustained data rates as high as 60 Mbps.

### NEES Consortium

*http://www.nees.org*

NEESgrid

NEES Consortium, Inc. is the National Science Foundation (NSF)-funded, non-profit consortium charged with overseeing the George E. Brown, Jr. Network for Earthquake Engineering Simulation (NEES). NEES includes 15 large-scale, experimental sites, which feature such advanced tools as shake tables, centrifuges, a tsunami wave basin, and field-testing equipment. Distributed across 10 states, these facilities are linked to a centralized data pool and earthquake simulation software, bridged together by the advanced capabilities of Internet2's Abilene Network to form a national virtual earthquake engineering laboratory. The NEESgrid system allows off-site researchers to interact in real time with any of the networked sites.

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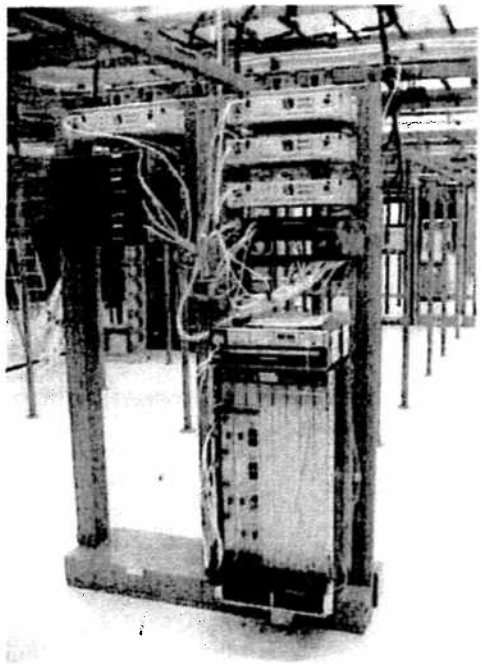
# The Abilene Observatory

The Abilene Observatory supports the development of an integrated data archive of the performance and network status information collected on the Abilene Network with the aim of providing information to researchers who wish to study an operational network in a way not possible in a laboratory environment or on the commercial Internet. The Abilene Observatory project—envisioned as an integral part of the Abilene network upgrade—provides a significant level of support for the network research community at Internet2 member universities. In addition, the Observatory provides for the collocation of network experiments and measurement servers developed by the research community.

## NMS Data Collection

Internet2 collects a variety of data, both for operational and research projects. There are four primary servers located in the Abilene racks, the Network Measurement Servers (NMS) provide the majority of the data measurements. They are standard PC type machines that have either 100 Mbps or 1 Gbps interfaces. Ongoing development will provide 10 Gbps interfaces in the near future. Data collected by the NMS machines is distributed to other database servers.



## Datasets

Data is continuously collected from the NMS machines in the following formats:

**Usage Statistics** – collected from the routers using SNMP. Includes a variety of router interface data.

**Flow Statistics** – collected using sampled Netflow data. Data is anonymized by zeroing the low-order eleven bits to protect privacy.

**Routing Data** – collected from measurement peers that collect IGMP and EGBP data.

**Latency Measurements** – collected using OWAMP methods.

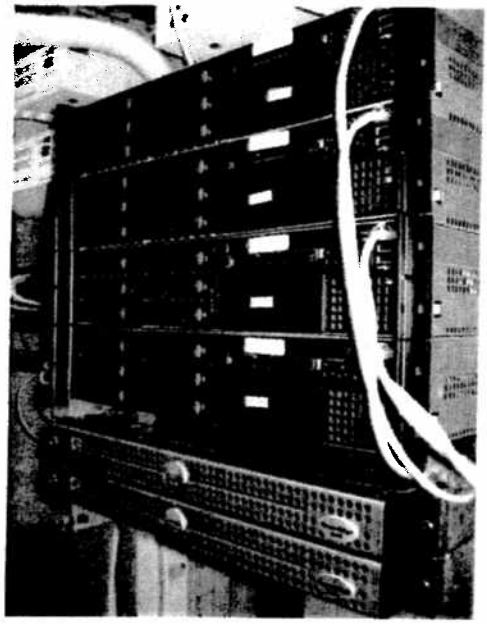
**Throughput Measurements** – collected using regularly scheduled iperf measurements.

**Router Data** – a variety of "show" statistics collected from the Abilene routers.

**Syslog Data** – data collected by syslog hosts reporting router information and logging.

The research community is encouraged to suggest other datasets important for network research.

## Collocation Projects



Researchers are encouraged to submit proposals to abilene@internet2.edu for collocation projects. Measurement or storage devices may be located in the Observatory, although space is limited and the devices must satisfy special requirements. For example, all devices must run on DC power, and have acceptable access interfaces.

The current collocation projects include:

- **PlanetLab** – http://www.planet-lab.org/
- **AMP Project** – http://amp.nlanr.net/
- **PMA Project** – http://pma.nlanr.net/

PlanetLab and AMP has servers deployed at all Abilene router nodes, and the PMA project has a *router clamp* at the Abilene Indianapolis router node.

## Examples of Current Research Projects

**The Wisconsin Advanced Internet Laboratory (WAIL)** – Flow sampling and anomaly detection using Abilene flow data. http://wail.cs.wisc.edu/

**Network Research Lab at Case Western Reserve University** – The presence and incidence of alpha flows in backbone links. http://vorlon.ces.cwru.edu/~vxl11/netlab/

**Kent State University Department of Computer Science** – Traffic management and QoS provisioning in IP networks. http://www.cs.kent.edu/department/index.html

**Boston University Department of Computer Science** – Spatio-temporal network analysis. http://cs-www.bu.edu/

**University of Minnesota MINDS Project** – Develop high performance data mining algorithms and tools. http://www.cs.umn.edu/research/minds/

**Computer Networks Research Group, Department of Computer Science, University of Massachusetts at Amherst** – Temporal-spatio correlations in network traffic on the Abilene network. http://www-net.cs.umass.edu/

**Internet Tsunami Warning System Project** – Automatic detection of network attacks.

**Niagara Project, University of Wisconsin-Madison and the Oregon Health & Science University** – Query processing over data streams. http://www.cse.ogi.edu/dot/niagara/

**Department of Computer Science, University of Pennsylvania** - Impact of aggregation of traffic on routing performance. http://www.cis.upenn.edu/

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**abilene.internet2.edu/observatory**

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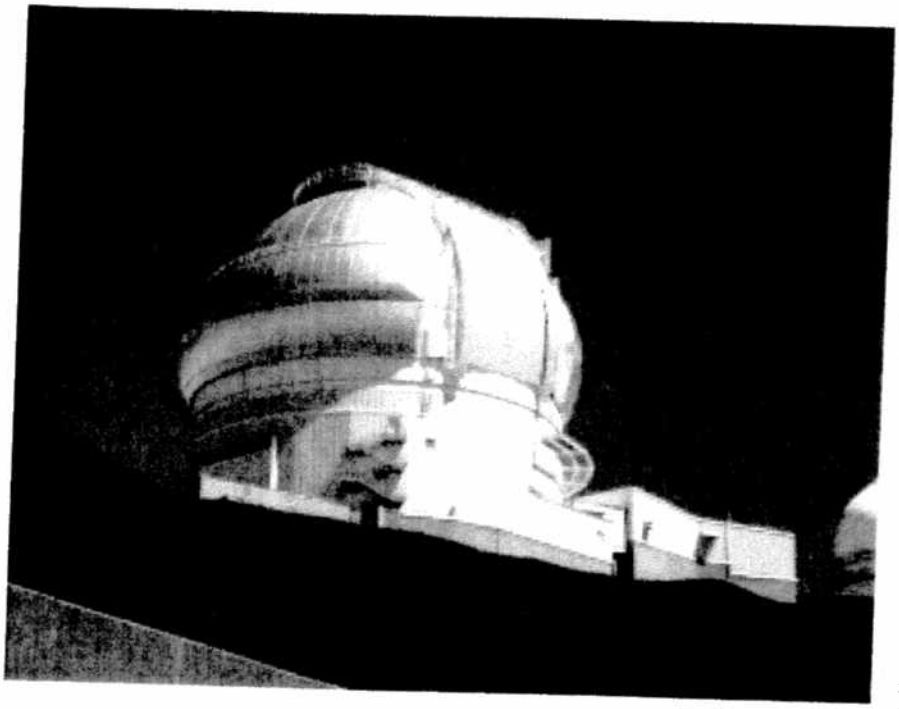
Internet2 applications enable collaboration among people and shared, interactive access to information and resources in ways not possible on today's Internet. Interactive collaboration, real-time access to remote resources, shared virtual reality, and large-scale, multi-site computation and data mining are examples of just some of the high-performance networking applications that researchers at Internet2 member universities are developing and using today.



### The nanoManipulator

University of North Carolina at Chapel Hill

*http://www.cs.unc.edu/Research/nano/*

The nanoManipulator is an interface to scanning probe microscopes (SPM) allowing users to see, feel, and manipulate samples ranging in size from DNA to single atoms. The nanoManipulator allows the user to control the SPM, view interactive 3D visualizations of the data, and feel the shape of the sample through a force-feedback device. A nanoManipulator can be used collaboratively by scientists in a "virtual laboratory" environment that allows remote access to a shared microscope and previously collected data. During collaboration, the nanoManipulator transfers video and system control data—all having different bandwidth, loss, and latency (delay) requirements. In contrast to some applications that have "bursty" bandwidth demands, the typical scientific experiment using the nanoManipulator lasts for many hours, creating a long-lived high demand on the network.

## Remote Instrumentation



### The Gemini Observatory

Association of Universities for Research in Astronomy

*http://www.gemini.edu/*

The Gemini Observatory is the result of a multi-national project to build twin 8.1 meter astronomical telescopes in Hawaii and Chile, making the skies in both the northern and southern hemispheres fully accessible to astronomers. High-performance networks enable these mountaintop telescopes to be operated remotely, in real-time, by astronomers in sea level-based control rooms. The high-performance connection also allows scientists to collaborate via videoconferencing, and will enable the observatories to share more of their findings with the public through techniques such as virtual observatory tours and live video to museums, planetaria and classrooms worldwide. Eventually, astronomers with access to Internet2 high-performance networks, in conjunction with international network partners, will be able to 'observe' using the Gemini telescopes from authorized remote sites, without having to travel to Hawaii or Chile.

## Interactive Collaboration

### The Access Grid

Argonne National Laboratory

*http://www.accessgrid.org/*

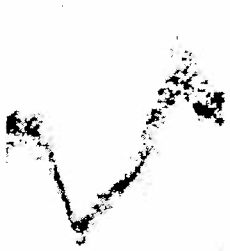
Large-scale scientific and technical collaborations often involve group-to-group interactions with multiple teams working together. The goal of the Access Grid project is to explore and support the requirements of group-to-group interactions across the computational grid. The Access Grid consists of large-format multimedia display, presentation, and interaction software environments; interfaces to grid middleware; and interfaces to remote visualization environments. Access Grid nodes are "designed spaces" that support the high-end audio/video technology needed to provide a compelling and productive collaborative experience. By providing access to these resources, the Access Grid supports large-scale distributed meetings, seminars, lectures, tutorials, and training.

# Distributed Computing

### National Scalable Cluster Project

University of Illinois at Chicago
University of Pennsylvania

*http://www.ncdm.uic.edu/*
*http://nscp.upenn.edu/*



The National Scalable Cluster Project (NSCP) has pioneered the application of cluster computing and high performance wide area networks to a variety of problems in data mining and data intensive computing. Using a testbed called the Terabyte Challenge, the NSCP develops the next-generation tools and standards to manage and mine massive (terabyte to petabyte) collections of data, specifically those that are geographically distributed. The Terabyte Challenge has been used as an Interoperability testbed for the development of the Predictive Model Markup Language (PMML) and has also been used in the development of DataSpace, an infrastructure to explore and mine remote, distributed data in real-time. Shown here is a graphical representation of climate data obtained using the DataSpace Transfer Protocol (DSTP). In this plot of ozone (an attribute) versus latitude (Universal Correlation Key) we are able to see the distribution globally.

### Grid Physics Network

University of Chicago
University of Florida

*http://www.griphyn.org/*

The Grid Physics Network (GriPhyN) collaboration is a team of experimental physicists and information technology researchers who are implementing the first petabyte-scale computational environments for data intensive science. Using Internet2 high-performance networks, GriPhyN will allow geographically dispersed extraction of complex scientific information from massive datasets, provide access to large-scale computational resources, and enable collaboration among worldwide scientific communities. GriPhyN will initially give scientists access to the vast amounts of data that will flow from four large-scale physics and astronomy experiments. GriPhyN will be capable of storing 10 petabytes of data. In addition to the Abilene network, other high-performance networks, including ESnet, NREN, I-WIRE, and international connections through STAR TAP and StarLight, will be used to share data throughout this globally distributed community of scientists.

# Networked Virtual Reality

### Virtual Harlem

University of Missouri – Columbia
Central Missouri State University
University of Illinois at Chicago

*http://www.evl.uic.edu/cavern/harlem/*

Virtual Harlem is a virtual reality environment originally developed in collaboration with University of Missouri-Columbia to supplement African American literature courses at Central Missouri State University. Students are able to step through a virtual 'portal' to the 1925–1935 New York Harlem Renaissance to navigate the city streets, interact with key figures, and listen to music written and popularized during the era. More recently, the University of Illinois at Chicago's Electronic Visualization Laboratory translated the Harlem experience to a fully immersive CAVE environment, establishing an experimental testbed for a diverse group of educators and researchers. Virtual Harlem has also been deployed as the educational component of a Harlem, New York project to bring high-speed networking to five community technology centers offering under-served communities access to hardware and software.

### TIDE2

University of Illinois at Chicago

*http://www.evl.uic.edu/cavern/TIDE/*

Image courtesy of the Electronic Visualization Laboratory, University of Illinois at Chicago

Tele-Immersive Data Explorer 2 (TIDE2) is a tele-immersion tool that allows distantly located scientists to query and visualize large, multi-dimensional datasets. It features out-of-core memory management and playback tools, and is supported by CAVERNsoft, a cross-platform tele-immersion toolkit for the Grid developed at the University of Illinois at Chicago's Electronic Visualization Laboratory. TIDE2 is designed to be a reusable framework to facilitate the construction of other domain-specific data exploration applications challenged with the problem of having to visualize massive datasets.

www.internet2.edu

Some of the largest consumers of advanced networking on campuses are not in the physics, engineering or computer science departments. Using high-capacity infrastructure to create global stages, enable remote instruction, allow participatory discovery, and open access to rich collections of media–Internet2's Arts & Humanities communities are redefining how they create, teach, perform, and collaborate.

PERFORMANCE

Photo courtesy of the University of Texas at Austin

## The Miró Quartet: Live & Virtual

*http://arts.internet2.edu/fall2004-perfevent.html*

During the Fall 2004 Internet2 Member Meeting, an evening performance event, *The Miró Quartet: Live & Virtual,* showcased the use of cutting-edge networking and streaming technologies, and featured the world-renowned Miró Quartet, a group comprised of University of Texas at Austin faculty. The event took place in two auditoriums with the audience switching venues during intermission. In the first auditorium, the audience saw and heard the string quartet in person. In the second, the audience saw the performance via real-time streaming High Definition Television (HDTV) and 10.2 channel immersive sound technology, developed by the Integrated Media Systems Center at the University of Southern California (USC). The 10.2-channel audio, projected over 26 speakers, allowed engineers to simulate how sound from an in-person performance reflects off acoustic surfaces in three dimensions. The HD stream featured four parallel channels, which captured each of the performers on stage individually. The performance served as a prototype for performing for an audience in two smaller auditoriums.

## Telematic Choreography

*http://dance.fsu.edu/telematics/events/wsu3304.html*

Photo courtesy of Maggie Allesee Department of Dance, WSU

The Florida State University (FSU) Department of Dance used Internet2's Abilene Network to provide long-distance coaching for dance students at the Wayne State University (WSU) Maggie Allesee Department of Dance. This interactive rehearsal session enabled internationally renowned choreographer and FSU Professor Jawole Zollar to observe and coach WSU dancers using interactive video and audio as they rehearsed excerpts from her work *Hair-Stories.* This telematic dance coaching session was the inaugural event of the Black Box Studio, a technology-enhanced FSU facility for video documentation, telematic research, and multimedia theater design. "Telematics"—a term created to describe the blending of computers and telecommunications technologies—provides a set of applications often used in the delivery of distance education. According to FSU Assistant Professor Tim Glenn, faculty researcher in dance telematics, "Advanced network technology opens the door to a whole new approach for how we create, teach, and perform dance works. As a result, the art of dance is redefined by incorporating the tools of new technologies into the dancers' experience. "

Photo courtesy of Arctic Region Supercomputing Center

## Art on the Grid

*http://www.uaf.edu/news/featured/05/artgrid/*

Instead of a physical location that is "somewhere," the Access Grid provides a virtual location that is "everywhere." Using the Access Grid, an ensemble of multimedia large-format displays and interactive visualization environment, the University of Alaska Fairbanks presented musical artist Valerie Naranjo to 26 locations around the world. Valerie is the percussionist for the Saturday Night Live Band and Drum Principal and Arranger for the Broadway production of *The Lion King.* During her session, she performed on the gyil (pronounced "Jee-lee", an African xylophone), the marimba, sang Native American songs and lectured about her music. She also directed remote participants in call and response singing, and ended the clinic with a Q&A session. Students and faculty from five university percussion programs participated: University of Alaska Fairbanks, University of New Mexico, University of South Dakota, University of Maine, and Jackson State University. Other participants included public school students, teachers, and music enthusiasts in the Access Grid community. This project was coordinated through "Art on the Grid", a collective of visual, media, and musical artists/educators who are developing productions on the Access Grid in order to explore its strengths, weaknesses and inherent potential. For more information about Art on the Grid, visit http://arts.internet2.edu/files/Percussion-and-Internet.pdf

OUTREACH FOR MUSEUMS

Photo courtesy of NOAA

## Return to the Titanic

*http://www.clevelandart.org/educef/titanic/html/*

The Cleveland Museum of Art provided a live portal to a unique interdisciplinary experience, *Return to The Titanic*. A series of satellite broadcasts featured live video from the depths of the Atlantic Ocean chronicling Dr. Robert Ballard's return expedition to the Titanic. Serving as the Ohio location, the Cleveland Museum of Art created a bridge for its community to the historical, archaeological, and scientific significance of the Titanic site.

A satellite system on the expedition's research vessel sent a real-time stream to VBrick Systems networked video appliances, located at Mystic Aquarium and Institute for Exploration in Connecticut, and then streamed live in MPEG-2 and MPEG-4 video formats over the Abilene Network to the Cleveland Museum of Art where the program was supplemented by an special overview of works of art reminiscent of the period.

EDUCATION

Photos by Fabio Bis

## Transatlantic Master Class

*http://www.nws.edu*

The 2005 GARR conference in Pisa, Italy—hosted by GARR, the Italian Academic and Research Network—invited members of the Internet2 Arts and Humanities community to help stretch the boundaries of technology-enabled, simultaneous, remote learning and teaching. Technical teams from GARR and the New World Symphony created virtual studio space for viola maestro, Hillary Herndon, at the New World Symphony, and viola student, Anna Simeone, from the Conservatory of Music in Pisa. Bridging languages through translators and distance through technolgy, student and teacher interacted during this live musical exchange. The broadcast, the first of its kind between Europe and the US, used two laptop computers: one receiving the 30 Mbps NTSC signal from Miami and converting it to PAL, the other sending the outgoing PAL signal to Miami at 30 Mbps where it was decoded using DVTS software, resulting in an aggregate bandwidth of 60 Mbps. In addition to the conference attendees on site, 170 viewers attended by netcast.

COLLECTIONS

## The EVIA Digital Archive

*http://www.indiana.edu/~eviada/*

Photo courtesy of R. Thomas Bray, Digital Media Commons, University of Michigan

While most research happens in libraries and archives, ethnomusicologists depend on the products of "fieldwork" for their study. World music events rarely involve only the sound of music, but many additional facets of creative communication. Video recordings, because of their ability to capture not only sound but the multiple facets of creative communication that surround it, are regarded as the recording tool of choice.

Preserving these video recordings and making them easily accessible for teaching and research is the aim of the Ethnomusicological Video for Instruction and Analysis (EVIA) Project. A joint effort of Indiana University and the University of Michigan, and supported in its initial phase by the Andrew T. Mellon Foundation, the EVIA project is coordinated by a team of experts in ethnomusicology, archiving, video, intellectual property, and digital technology. Ultimately, project plans include providing guidelines for future archives and establishing a functioning digital repository and delivery system for the current collection, which contains approximately 150 hours of digital video. Using the advanced network capabilities of Internet2, EVIA will provide high quality video streams to scholars for new research endeavors and to teachers for creating rich learning experiences.

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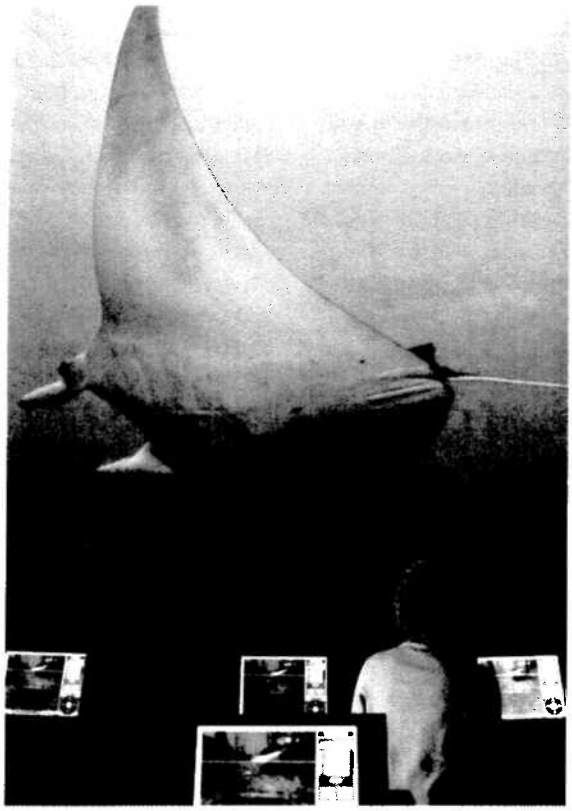
www.internet2.edu

Streaming high-quality digital video over advanced networks is essential to nearly all Internet2 applications, whether in the arts, sciences, or healthcare. Many initiatives in our member community are producing a new generation of digital video applications, advancing worldwide research and education.



## Streaming Video



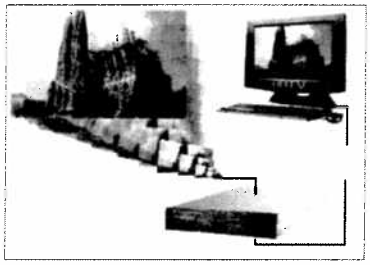
**Live Coast-to-Coast Undersea Video**
University of California, Santa Cruz
University of Connecticut
VBrick Systems

*http://mysticaquarium.org/newthings/articles/immersion.asp*

Visitors at Connecticut's Mystic Aquarium immerse themselves in an underwater world 3,000 miles away by remotely controlling underwater cameras in California. Using interactive consoles at the Mystic Aquarium's Immersion Institute, visitors control three video cameras on an underwater submersible in Monterey Bay, the largest U.S. marine sanctuary. The live video is encoded into DVD-quality MPEG-2 and sent at an average rate of 6 Megabits per second (Mbps) to the University of California, Santa Cruz, where it travels across Internet2 high-performance networks to the University of Connecticut and on to the Mystic Aquarium.

**High Definition Video Array**
ResearchChannel Consortium

*http://researchchannel.org/inside/i2wg/projects.asp*



ResearchChannel pushes the boundaries of High-Definition (HD) video over advanced networks with a variety of projects ranging from uncompressed, extreme-quality HD at 1.5 Gbps; to editable, studio-quality HD at 270 Mbps; to production-house-quality HD at 45 Mbps; to viewer-quality HD-to-the-desktop at 19.2 Mbps. Having successfully tested these prototypes, ResearchChannel will continue to develop projects involving networking configuration and hardware and software development. Areas of further work include uncompressed HD for interactive videoconferencing, decreasing the latency of 270 Mbps HD, and improving the desktop HD client.

**Super High Definition Video**
Nippon Telegraph and Telephone Corporation
University of Illinois at Chicago
University of Southern California

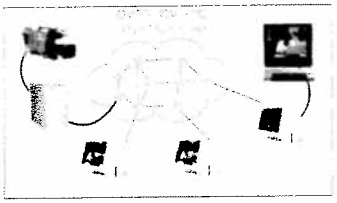
*http://www.onlab.ntt.co.jp/en/mn/*

The successful transport of a Super High Definition (SHD) stream over advanced networks occurred at the Fall 2003 Internet2 Member Meeting, where an NTT system at the UIC Electronic Visualization Laboratory sent SHD to the Robert Zemeckis Center for Digital Arts at the USC School of Cinema-Television. SHD scientific visualizations and student films—four times the resolution of HDTV—were compressed to 200-400 Mbps streams using an experimental JPEG codec, stored, and sent to an NTT real-time decoder. NTT's prototype SHD frame buffer then fed an eight-megapixel projector for display.

# Interactive Video

### Digital Video Transport System
WIDE Project Japan

*http://www.dvts.jp/en/*
*http://www.sfc.wide.ad.jp/DVTS/software/*



Digital Video Transport System (DVTS) enables high-quality, real-time communication using free, downloadable software and off-the-shelf video and audio equipment. DVTS streams DV across advanced networks at 30 Mbps using Internet Protocol version 4 (IPv4) or 6 (IPv6). The DVTS client for Windows XP supports IPv6 unicast and multicast. PAL support has been included in the Mac OS X and Linux clients, and redundant audio transport capabilities have been added to improve audio performance in low packet-loss conditions. DVTS has been used to link instructors with students, and researchers with research laboratories around the globe.

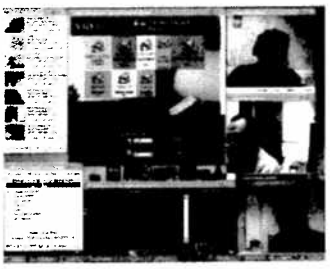
### The Access Grid 2.0
Argonne National Laboratory

*http://www.accessgrid.org/*

The Access Grid is a set of resources for multi-site, group-to-group collaborations over advanced networks, consisting of large-format video displays of participants, presentation sharing, and multimedia streaming. Access Grid version 2.0, released in May 2003, has been completely rebuilt using the Globus Toolkit for security and access to the Grid infrastructure. This allows developers to create advanced collaborative applications using the Access Grid Toolkit. The new Access Grid is capable of supporting a wider range of client platforms, including desktop computers, laptops, and traditional room-based nodes. The Access Grid project at Argonne National Laboratory is supported by the National Science Foundation, the U.S. Department of Energy, and Microsoft Research.

### Virtual Rooms Videoconferencing System 3.0
California Institute of Technology

*http://vrvs.org/*



Virtual Rooms Videoconferencing System (VRVS) is a web-based system for interoperable videoconferencing and collaborating. VRVS supports multiple platforms—Windows, Mac, Linux, Unix—and diverse collaborative applications—Access Grid, H.323 videoconferencing, QuickTime, chat, desktop sharing, and, soon, Microsoft Messenger. Ninety-five percent of the code was re-written for the spring 2003 release of VRVS 3.0, which includes an advanced booking system, new virtual rooms for meeting spaces, a streamlined web-based user interface, firewall and NAT solutions, Access Grid tunneling, self-selection of video streams, user authentication, and synchronized time zones. No port reservations are required in order to initiate a videoconference—simply book a room in advance for any number of participants to join. Funding provided by the National Science Foundation and the U.S. Department of Energy.

# End-to-End Performance Initiative (E2Epi)

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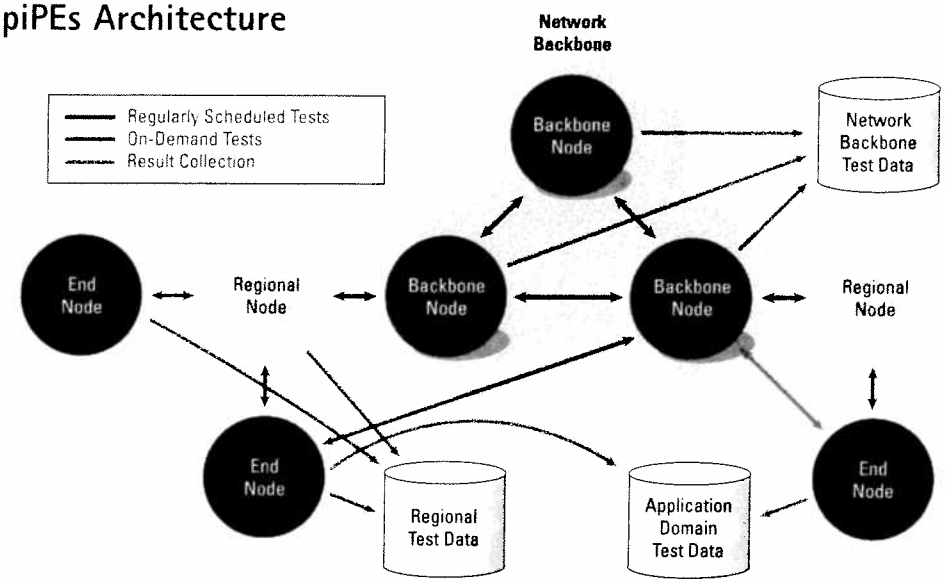
www.internet2.edu

For high-speed computing to become a reality, performance needs to be addressed. Users of state-of-the-art, 10 gigE backbone networks currently encounter many of the same problems faced by dial-up users. Internet2's E2Epi is creating a framework (E2E piPEs) for identifying the source of problems; developing measurement and troubleshooting tools; collaborating with researchers on related projects to avoid duplication of effort; and fostering communication between researchers, network operators, and end-users.

## E2E piPEs Architecture




"In the ideal world, network users would have a tool that could tell a user where a problem is, what type of problem it is, and the person to contact for the resolution of the problem."

**JAMES D. BRUCE**
"Beyond Bandwidth," *EDUCAUSE Review*, vol. 38, no. 1 (January/February 2003): 30

## E2E piPEs

*e2epi.internet2.edu/ E2EpiPEs/*

With Internet2's E2E piPEs, the average user will have such a tool. In its final form, the E2E piPEs can determine the performance characteristics of the complete path by aggregating information about the segments that make up the path; problematic segments can be identified and reported, with supporting data, to the appropriate network administrator. The aim of this system is to reduce the "signal-to-noise ratio."

E2E piPEs is a framework that employs various tools, such as traceroute and Iperf, to run tests to provide information on loss, jitter, flow data, one-way latency, and throughput. Data collected from regularly scheduled tests is used by the Abilene Observatory to provide weekly reports on the status of the Abilene network.

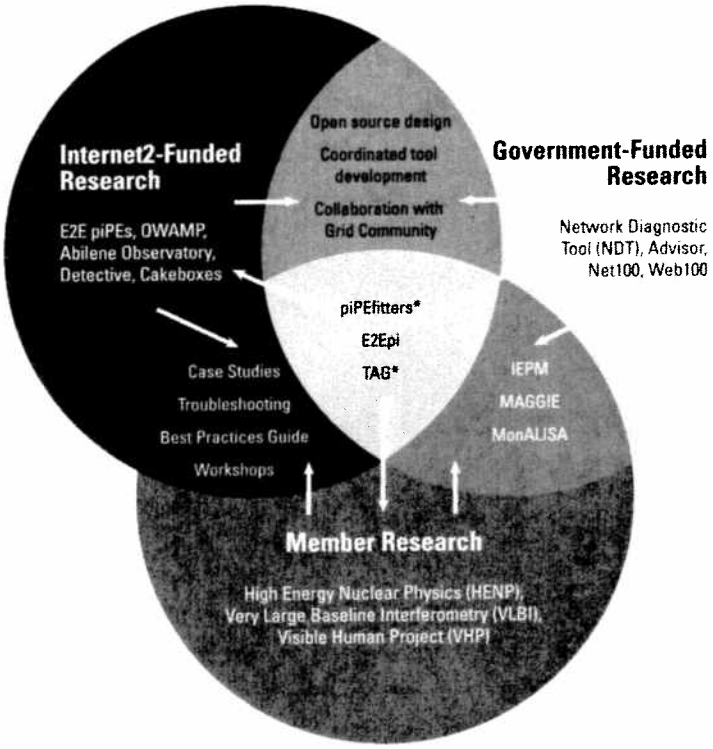
## Tool Development

*owamp.internet2.edu*
*bwctl.internet2.edu*
*www.itecohio.org/beacon/*

The E2Epi has supported development of three tools: OWAMP (One-Way Active Measurement Protocol), BWCTL (Bandwidth Control), and the H.323 Beacon, that provide users with methods to determine the location of common end-to-end performance problems. OWAMP helps a user determine whether latency is experienced on the inbound or outbound path. The BWCTL allows the scheduling of regular and on-demand authorized throughput tests in the presence of scarce resources. These tools are used by E2E piPEs and are part of Abilene quality control.

The H.323 Beacon tool measures and monitors videoconference sessions, qualifies sessions, and can be used as a debugging tool to troubleshoot problems. This tool is used by the Internet2 Commons videoconferencing service (commons.internet2.edu).

## E2Epi Collaboration




*

**piPEfitters**: Volunteers working on specific pieces of the E2E piPEs architecture.
**TAG** (Technical Advisory Group): Experts who provide biweekly input on E2Epi projects.

## Collaboration

Such projects as E2E piPEs and NLANR's Advisor are combining results of different measurement tools into a richer, broader, and leveraged collection of solutions for the growing knowledge base. The E2Epi has established working relationships with specific application communities (i.e., videoconferencing and multicast) and disciplines (such as high-energy and nuclear physics, radio astronomy, and health care) to help solve performance problems encountered by users. The Initiative continues to work on other Internet2-focused advanced applications, including distributed computation, digital libraries, distributed learning, digital video, tele-immersion and virtual laboratories. The E2Epi also works with such Internet2 corporate members as Apparent Networks to develop products for the Internet2 community that are appropriately tuned and provide high-performance capabilities.

## Communication

Performance problems can be identified and solved more efficiently through communication—integrated and shared within an established knowledge base, using successful measurement performance stories derived from research and engineering communities. The E2Epi collects and disseminates brief case studies of problems encountered and their solutions.

The E2Epi uses their website to: disseminate these case studies; solicit member input in developing/collecting "best practices" for campus networking infrastructure and troubleshooting techniques; provide links to related documents and websites; and foster an open discussion of end-to-end performance tools, techniques, and issues (e2epi.internet2.edu).

The E2Epi has hosted several workshops on end-to-end issues, bringing together researchers, network engineers, and end-users to discuss the problems encountered and methods by which a user could be more informed. In December 2003, for example, with funding from an NSF grant, the E2Epi brought together a number of topical experts to create a "road map" of the research currently in progress and how each piece links with the others. This ensures that all the necessary measurement and performance tools are being developed and that the tools will be interoperable.

At several meetings each year, the E2Epi sponsors tutorial sessions (focusing on using the latest measurement/troubleshooting tools) and update sessions (where researchers provide status reports on related projects). The E2Epi also provides ongoing support for the Peer-to-Peer Working Group (p2p.internet2.edu) and the Measurement Special Interest Group (measurement.internet2.edu).

200312-IS-E2Epi

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www.internet2.edu

Internet2 health science applications are enabling breakthroughs in medical education, research, and clinical practice. Doctors are gaining access to specialists for remote consultations, students are learning anatomy with the support of new tools and technologies, and smart databases are assisting with diagnosis and knowledge sharing among researchers. All of these advancements are made possible by Internet2's advanced networks and the emerging technologies that facilitate the secure transfer of large data sets and access to shared resources.

## PathMiner: Image Guided Decision Support Project

UNIVERSITY OF MEDICINE & DENTISTRY OF NEW JERSEY – ROBERT WOOD JOHNSON MEDICAL SCHOOL

THE CANCER INSTITUTE OF NEW JERSEY

*http://www.umdnj.edu*

*http://www.cinj.org*

As the amount of information archived digitally worldwide continues to grow, it becomes increasingly difficult to index information for future relocation or retrieval. This is an especially challenging problem for images, which are often indexed using a single text-based label. Researchers at the University of Medicine & Dentistry of New Jersey, Rutgers University, and the University of Pennsylvania have developed content-based image retrieval tools for diagnostic pathology. The NIH-funded *PathMiner* system that they have developed is a web-based set of tools for interactive telemedicine, intelligent archiving, and automated decision support in pathology. By utilizing Internet2's advanced networks, the *PathMiner* system enables individuals to submit query images from local or remote computers—or robotic or virtual microscopes—to search engines that automatically identify and retrieve digitized pathology data of statistically-similar tissues from within distributed databases. Eventually, the system will also support the integration of high-resolution video streaming across Internet2 advanced networks.

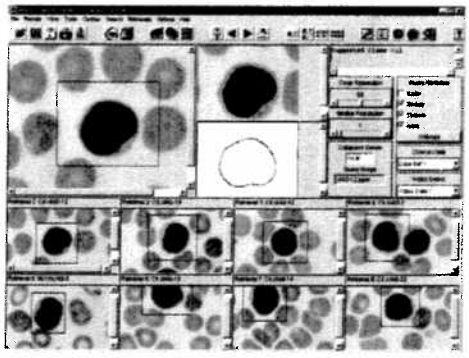

Image courtesy of UMDNJ - Robert Wood Johnson Medical School

Image courtesy of BIRN

## Biomedical Informatics Research Network

INTERNET2 UNIVERSITY MEMBER BIRN PARTICIPANTS

*http://www.nbirn.net*

Drawing upon the expertise and technologies available at universities, hospitals, and other institutions, the Biomedical Informatics Research Network (BIRN) is building an infrastructure of networked high-performance computers, data integration standards, and other emerging technologies, to pave the way for medical researchers to transform the treatment of disease. Launched in 2001 as an initiative of the National Institutes of Health's National Center for Research Resources, the BIRN is prototyping a collaborative environment for biomedical research and clinical information management.

BIRN leverages Internet2's advanced networking infrastructure to enable collaboration and data sharing for biomedical research. With Internet2 production resources and networking facilities like the OptIPuter, BIRN is able to respond to the current and future needs of the biomedical research community. This cyberinfrastructure encourages biomedical scientists and clinical researchers to make new discoveries by enabling sharing, analysis, visualization, and data comparisons across laboratories. The growing BIRN consortium currently includes over 20 Internet2 member organizations and involves more than 40 research groups from universities and hospitals located in the United States and United Kingdom interconnected by Internet2 advanced networks and their international partner networks, which provide a stable backbone for all distributed data within the BIRN.

## Remote Stereo Viewer

STANFORD UNIVERSITY

UNIVERSITY OF WISCONSIN-LACROSSE

*http://summit.stanford.edu/*

*http://www.visu.uwlax.edu/NGI/RSV.html*

Medical students at Stanford University are using a new educational tool called Remote Stereo Viewer (RSV) to complement their traditional gross anatomy coursework. The tool was developed through a collaboration of Stanford's SUMMIT lab and the Computer Science department at the University of Wisconsin-La Crosse, and was partially funded by the National Library of Medicine. Internet2 advanced networks make it possible for the RSV application to enable medical educators and students in different locations to collaboratively view three-dimensional interactive high-resolution stereo photographs of anatomical structures. The selected anatomical specimen can be viewed in various stages of dissection, which enables students to move between the layers and offers them a better understanding of the intricacies and complexity of the feature being studied. To develop this tool, rotated sequences of stereo image pairs were produced by volumetric rendering of the visible female and by dissecting and photographing a cadaveric hand. The images are stored on a server and individually downloaded to a workstation on demand. Individual users take the role of "leader" or "follower" to navigate through the specimen together in real time, creating a virtual classroom between users at different workstations and different locations. RSV requires the high bandwidth of Internet2's advanced networks to accommodate the size of the high-resolution stereo images. The application also utilizes multicast, allowing participants at all workstations to simultaneously view the specimen navigation occurring at one workstation.

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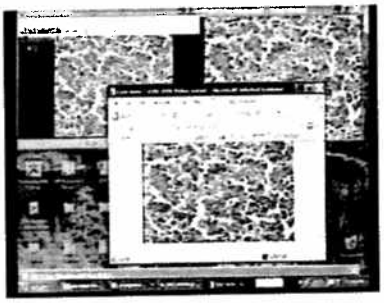

## DVTS for Telemicroscopy

UNIVERSITY OF PENNSYLVANIA

*http://www.uphs.upenn.edu/path*

Pathologists at the University of Pennsylvania Health System have been experimenting with Digital Video Transport System (DVTS) for high-quality video telepathology and telemicroscopy over Internet2 advanced networks. This simple and inexpensive method of transmitting high-quality video and audio enables doctors to perform consultations at remote hospitals where there is no pathologist on site, to offer second-opinion consultations, and to provide distance education. In Philadelphia, it is used by pathologists at the three hospitals that comprise the University of Pennsylvania Health System to perform real-time clinical case consultations. DVTS uses 30 Mbps uncompressed video to provide high-quality images with low latency. DVTS can also be used in multicast mode to allow three or more sites to participate in a single conference. DVTS is one of the principal areas of activity of the Internet2/ResearchChannel Working Group's BigVideo project group, which explores high-quality on-demand and streaming video applications.

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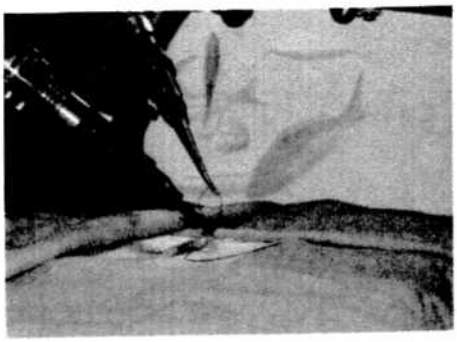
## Center for Surgical Innovation

UNIVERSITY OF CINCINNATI



*http://surgery.uc.edu/csi*

The Center for Surgical Innovation (CSI) at the University of Cincinnati was established to develop, assess, and disseminate new technologies in biomedical and surgical care. They have been at the forefront of telesurgery and surgical robotics, and are pioneering the application of advanced networking to these technologies. CSI and its partners modified the daVinci Surgical System—currently the only clinically supported surgical robotic system—to create a system capable of transcontinental stereoscopic robotic surgical intervention. Using Internet2's advanced networks, researchers are improving the system's image fidelity and decreasing latency, jitter, and packet loss in order to meet the high standards that clinical use demands. Providing surgeons the ability to mentor and perform procedures from remote locations will have a profound impact on the quality and type of care provided to soldiers on the battlefield, astronauts in space, undersea researchers, and even patients in remote geographic locations.

# International Partnerships

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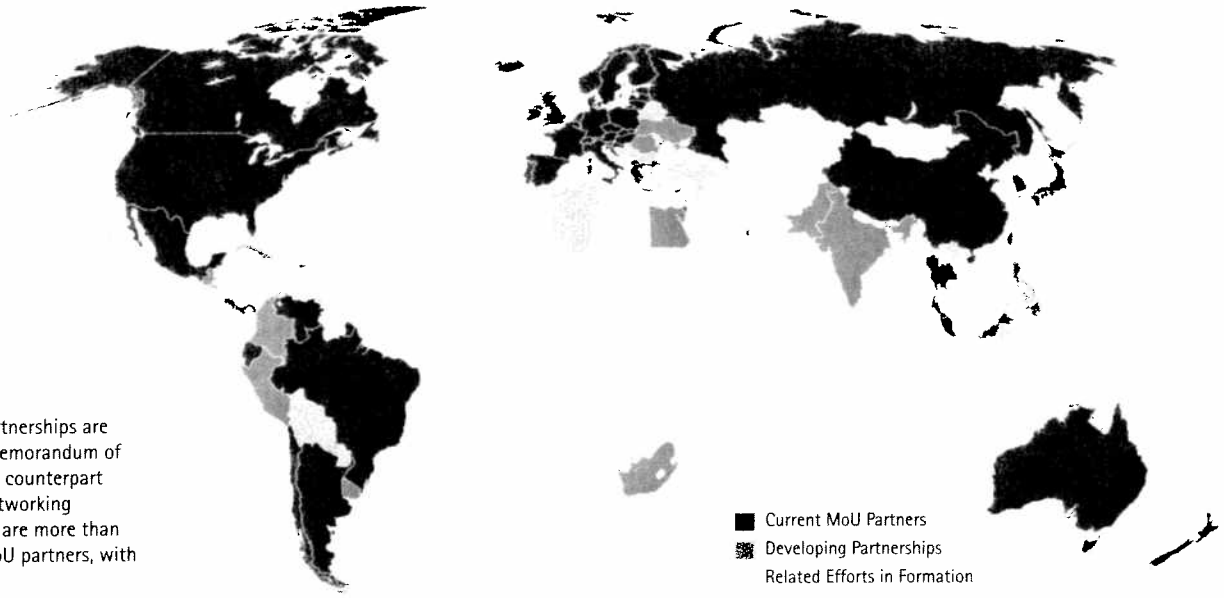
International partnerships link Internet2 members to research and education networking organizations around the world. The principal goal of Internet2 international partnerships is to enable global collaboration in research and education by providing access to advanced international networks. By creating a global proving ground for new technologies, and by providing channels for international Internet technology transfer, Internet2 international partnerships also help to ensure that the next generation of Internet technologies and applications will be globally interoperable.

## INTERNATIONAL MoU PARTNERS




Internet2 international partnerships are established by signing a Memorandum of Understanding (MoU) with counterpart research and education networking organizations. Today there are more than forty-five international MoU partners, with more on the way.

## Global Proving Ground

Most international MoU partners operate networks which interconnect with Internet2's Abilene network. Internet2 works closely with its international partners, and with key Internet2 member institutions involved in international connectivity projects, to make a coherent global research and education networking infrastructure available to its members. Internet2 member institutions contribute by managing key international exchange facilities such as StarLight, Pacific Wave, MAN LAN and AMPATH, as well as international connections such as APAN/TransPAC, Euro-Link and GLORIAD. The US National Science Foundation provides important funding to a number of these projects.

Internet2 members and international partners are using this global infrastructure to develop and test new technologies on a scale not possible in the commercial Internet. For example, partners in the United Kingdom have funded staff to work on the Internet2 End-to-End Performance Initiative's performance monitoring system, called piPEs. These partners' involvement not only provides resources to the Internet2 community, but also helps to ensure interoperability of performance monitoring systems between the US and Europe.

# Global Collaboration

Internet2 international partnerships support a wide variety of projects; here are a few examples.

### Logistical Computing and Internetworking (LoCI)

*loci.cs.utk.edu*

Logistical Computing and Internetworking (LoCI) is a field of research exploring the optimal coordination and use of the enormous quantities of storage, computational power, and bandwidth now available worldwide. The LoCI Lab at the University of Tennessee is leading the construction of a global logistical networking infrastructure, which currently includes data management nodes that span research and education networks on five continents. The LoCI Lab aims to integrate these capabilities to form a coherent system for the distribution, staging, processing and delivery of large quantities of data.

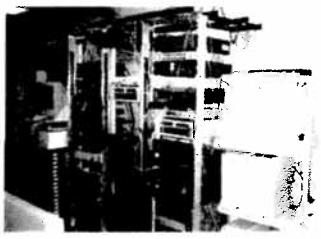
### European Union and US Mid-Atlantic eXchange (EUMAX)

*www.eumax.isn-oldenburg.de*

The EUMAX project is developing an international foreign language, business, and technology curriculum, which students will complete through a combination of online curriculum delivery and travel abroad for further study and internships. A central feature of this project is the use of high-performance videoconferencing to connect US and European universities via the Abilene and GÉANT research and education networks. EUMAX researchers are mindful that community-building and the transmission of lessons learned are crucial for the success of future endeavors of this type; providing a model for such future efforts is a principal goal of their work.

### Virtual Network Engineering Lab (VNELab)

*vnelab.cs.tamu.edu*



Located at Texas A&M University, VNELab provides students of network engineering with access to state-of-the-art equipment. Texas A&M is using VNELab's Web Access Exercise System (WAES), together with connectivity between Abilene and CUDI (Mexico's national research and education network), to expand access to this equipment to students at the Universidad Autónoma del Estado de Hidalgo and the Universidad Nacional Autónoma de México.

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Number of Addresses in IPv4

4,294,967,296

World Population (2003 est.)

6,314,000,000

Number of Addresses in IPv6

340,282,366,920,938,463,463,374,607,431,768,211,456

# IPv6

*ipv6.internet2.edu*

IPv6 is the next version of the Internet Protocol, the data packaging and routing standard on which the Internet is based. The current version is IPv4; IPv5 was experimental and was never widely deployed.

IPv6 offers several improvements over IPv4. Most importantly, with 128-bit Internet addresses instead of the 32-bit addresses of IPv4, IPv6 vastly increases the number of addresses available from about 4 billion to about 340 trillion trillion trillion.

Given the continued rapid growth of the Internet, ensuring an abundance of addresses is crucial. The proliferation of wired and (especially) wireless devices means that in the near future not one or two, but many addresses will be required for each person who uses the Internet. The techniques currently employed to cope with the shortage of IPv4 addresses are reaching their limits, and many of these techniques – such as temporary address assignment and network address translation – compromise engineering principles fundamental to the Internet's success, thus jeopardizing its future growth.

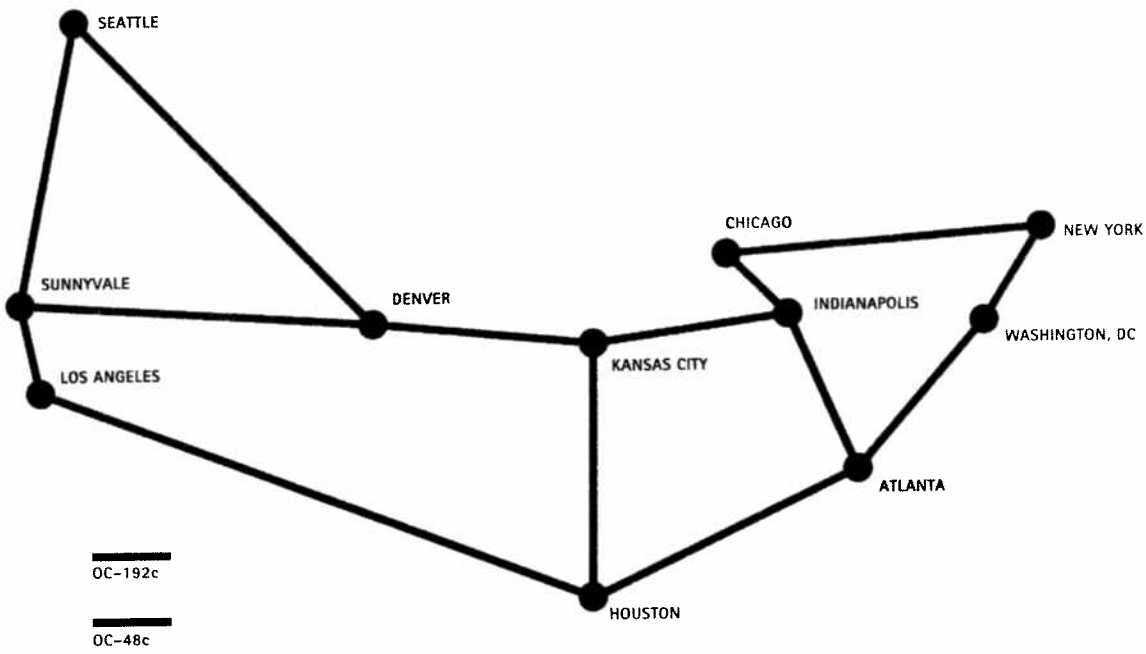
**Internet2 is committed to offering world-class IPv6 connectivity to its members, affiliates and partners.**

The Internet2 **IPv6 Working Group** coordinates Internet2's IPv6 efforts. The working group discusses and implements IPv6 policies, responds to deployment questions, and disseminates IPv6-related news.

**IPv6 hands-on workshops** provide opportunities to learn about the IPv6 protocol and how to design, implement and maintain an IPv6 network. All workshop materials, including presentations and lab equipment, are available for Internet2 members, affiliates and partners to use in providing their own regional workshops.

*continued on back*

# Abilene's Dual-Stack IPv4/IPv6 Network




**Abilene** is a dedicated backbone network for the Internet2 community. Abilene is a dual-stack IPv4/IPv6 network and supports bandwidths of up to 10 Gbps; the network is designed to provide optimal performance to both IPv4 and IPv6 packets. Abilene connects high-performance regional networks to support the work of Internet2 members as they develop advanced Internet applications and the advanced networking capabilities needed to support them; many of these members and regional networks are now deploying IPv6. Abilene also maintains IPv6 peerings with many other US and international backbone networks, helping to secure the future of connectivity for research and education worldwide.

The Abilene backbone is monitored 24 hours a day, 7 days a week by the **Abilene NOC** at Indiana University. Abilene NOC engineers treat IPv6 as they would any production service and are experienced at handling IPv6 issues at the backbone, regional, and campus levels.

The Internet2 Technology Evaluation Centers **(ITECs)** in Ohio, North Carolina, California, and Texas are test facilities for Internet technologies being evaluated for deployment in the Abilene backbone and throughout the Internet2 networking infrastructure. Evaluating IPv6 technologies such as IPv6 routing and IPv6 multicast is a principal focus of the ITECs' work.

Internet2 is working to realize the potential of IPv6 for the global Internet community. Find out more at:

**Abilene:** *abilene.internet2.edu*
**Abilene NOC:** *www.abilene.iu.edu*
**ITECs:** *itecs.internet2.edu*
**IPv6 Working Group:** *ipv6.internet2.edu*

200403-IS-V6

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The National Internet2 K20 Initiative brings together Internet2 member institutions and innovators from primary and secondary schools, colleges and universities, libraries, and museums to extend new technologies, applications, middleware, and content to all educational sectors, as quickly and connectedly as possible. As of early 2005, there were 34 state K20 networks participating, enabling about 30,000 K20 institutions—including 23,388 K12 schools, 2360 public libraries, 594 community colleges, 852 four-year colleges and universities, and 74 museums, zoos, aquariums, and science centers—to connect to Internet2 advanced networks.

Experiences and Expertise

International Learning Communities

Rich Multi-Media Digital Libraries

Remote Instrumentation

Creating New Knowledge

Creating New Opportunities

MyK20 Community

**Lewis and Clark Then and Now: Linking the Trail to America's Students**
School District of Clayton, MO
Apple Computer

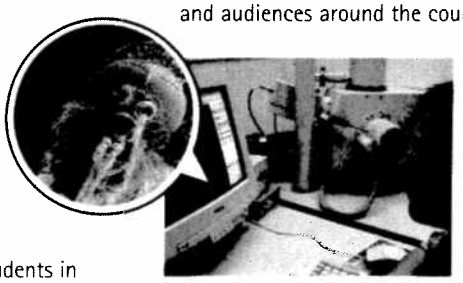
*http://www.ali.apple.com/lewisandclark*

From 2003 to 2006, the United States will commemorate the bicentennial of the Corps of Discovery's historic journey across America. Throughout the 2003-2006 school years, Lewis and Clark Then and Now: Linking the Trail to America's Students will follow various re-enactment groups as they retrace the three-year voyage of the Corps of Discovery. Many aspects of Internet2 are involved—including the Internet2 Commons H.323 Videoconferencing Service, the National Internet2 K20 Initiative, and the ResearchChannel Working Group—enabling students in classrooms nationwide to retrace Lewis and Clark's journey and understand how it shaped America today.

*Music Bridges*: K-12 Faculty-Driven Music Programs
Manhattan School of Music
St. Clair County Intermediate School District, MI

*http://www.msmnyc.edu/special/video*

Manhattan School of Music's distance learning program is partnering with Michigan's St. Clair County Regional Educational Service Agency to present music programs delivered via interactive videoconferencing over Internet2 advanced networks. St. Clair County, which includes 57 schools across 7 school districts, will receive offerings such as American Composers, A Personal Introduction to Opera, and the type of custom telementoring sessions that require the high-fidelity, broadcast-quality streaming audio and video available over Internet2. By eliminating the barriers of time and distance, Manhattan School of Music's faculty and student teaching artists can extend their expertise to students and audiences around the country.



**ImagiNations Remote Instrumentation Project**
Lehigh University

*http://www.lehigh.edu/~inimagin/*

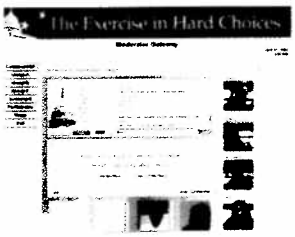
The ImagiNations project introduces K-12 students to electron microscopy and nanotechnology. The Center for Advanced Materials and Nanotechnology (CAMN) at Lehigh University uses Internet2 to offer K-12 students real-time remote access to the XL30 ESEM (environmental scanning electron microscope). Scale and surface area animations are available for the students' interaction, along with interactive image magnifications on the project website.

### The Exercise in Hard Choices

The University of Akron
Beachwood City School District, OH
Plain Local School District, OH
St. Clair County RESA, MI

*http://www.crfb.org/html/exercise.htm*

For over 20 years, the Committee for a Responsible Federal Budget has administered *An Exercise in Hard Choices*SM, an interactive budget exercise, in a face-to-face, "traditional" format. The Exercise gives participants the opportunity to role-play members of Congress as they debate spending and revenue options in small groups and arrive at a final federal budget for the year. The University of Akron has been engaged by the U.S. Department of Education for three consecutive years to develop, test, and evaluate electronic versions of the Exercise, making use of the low latency and end-to-end performance capabilities of Internet2 to facilitate high quality video connections among distant participants.




### Megaconference Jr.

Chester County Intermediate Unit, PA
MAGPI
St. Clair County RESA, MI
Several International Collaborators

*http://megaconferencejr.org*

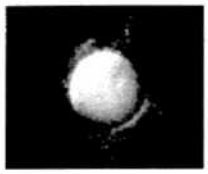
Megaconference Jr. is the first student-led international videoconference learning event for K-20 schools. This all virtual H.323 videoconference brings together students and teachers from around the world to showcase curricular project initiatives, increase cultural awareness and broaden understanding of the role advanced networks have in the 21st century world. In Megaconference Jr., students are involved in all aspects of the conference including planning, technical implementation and script writing.
A primary goal of Megaconference Jr. is for schools to form sustained collaborative projects to extend the learning environment to the world outside the classroom.


### Microscope Imaging Station

Exploratorium

*http://www.exploratorium.edu/imaging_station*

Located in San Francisco, the Exploratorium features hundreds of science, art, and human perception exhibits. The Exploratorium is a leader in the use of advanced networks to extend the outreach of museums as educational centers. The Exploratorium's Microscope Imaging Station gives museum visitors a unique opportunity to control research-grade microscopes and view stunning images of biological processes. The web site provides a large and growing collection of interactive high-resolution images and DVD-quality videos. The Exploratorium is developing a virtual microscope and activities for classroom use.



### Immersion Institute

Mystic Aquarium
Monterey Bay National Marine Sanctuary
NOAA
VBrick

*http://mysticaquarium.org/*

Visitors to Connecticut's Mystic Aquarium can immerse themselves in an underwater world 3,000 miles away by remotely controlling underwater cameras in California. Using interactive consoles at the Mystic Aquarium's Immersion Institute, visitors control three video cameras on an underwater submersible in the Monterey Bay National Marine Sanctuary, the largest U.S. marine sanctuary. Using VBrick Systems MPEG-2 encoder/decoders, the live video is encoded into DVD-quality MPEG-2 and sent at an average rate of 6 Megabits per second (Mbps) to the University of California, Santa Cruz, where it travels across Internet2 high-performance networks to the University of Connecticut and on to the Mystic Aquarium.

## Getting Involved

**The Internet2 K20 website has what you need to get engaged — project descriptions, people directories, collaboration tools, articles, news and events, and FAQs.**
http://k20.internet2.edu

200504-IS-K20

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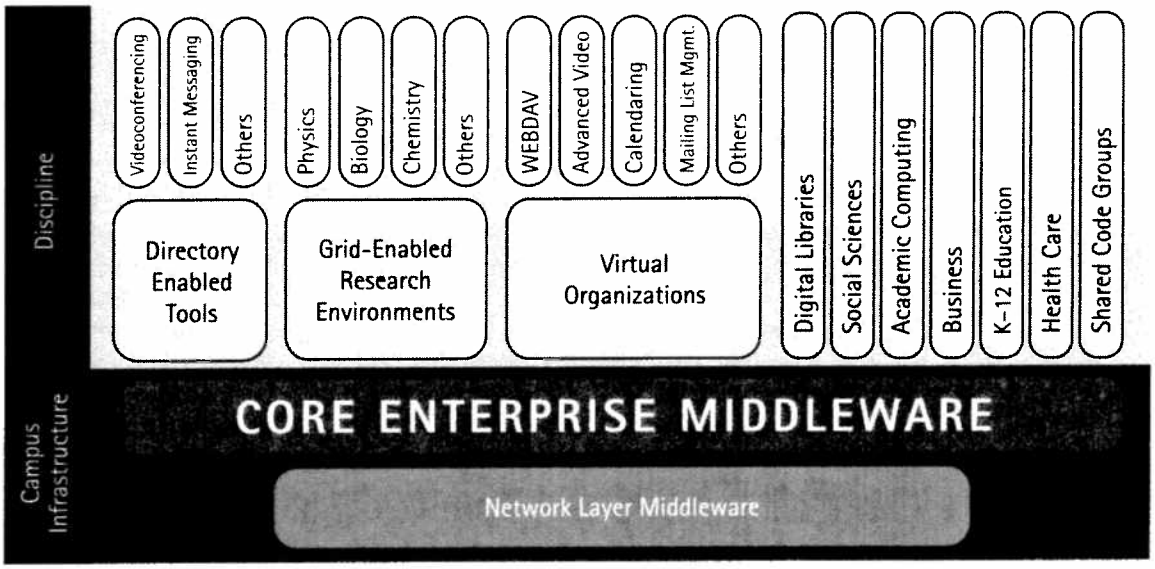
Middleware is a layer of software between a network and the applications that use it. Middleware is an infrastructure that manages security, access, and information exchange on behalf of applications to make it easier and more secure for people to communicate and collaborate. It is used both to find people and things, as with directory services, and to keep them confidential, as with security services.




## Why Middleware?

The absence of common, standard middleware solutions is a big problem for today's research and education networks. Addressing the opposing challenges of ensuring security and access, availability and privacy, a technology infrastructure—generically called "enterprise middleware"—is emerging throughout higher education, government, and corporate sectors.

Many of the online services and applications that campuses offer have similar requirements, which this infrastructure addresses:

- Are the people using these services who they claim to be?
- Are they members of our campus community?
- Do they have permission to use these services?
- Is their privacy being protected?

Applications either make do without these core middleware functions—in which case usability, security, and efficiency suffer—or applications perform middleware functions themselves, leading to competing and incompatible standards.

## What is the Internet2 Middleware Initiative?

The goal of the Internet2 Middleware Initiative is to contribute to the building of an international interoperable middleware infrastructure for research and education.

The Middleware Architecture Committee for Education (MACE), a group of leading higher education IT architects, provides overall direction and vision for the Initiative. Their working agenda is set by campus CIOs and partners and includes:

- Researching and developing architectures, software, methodologies, practices, and standards for campus IT middleware infrastructure.
- Encouraging the establishment of community-based middleware policy and technology infrastructures.
- Working with government, corporate, and other national and international communities to ensure integration.
- Promulgating the findings and deliverables to catalyze deployment across the research and education communities.

## Middleware Working Groups

While the vision is supplied by MACE, the research details are addressed by the Internet2 Middleware working groups. MACE forms these as needed to explore specific issues; below is a sampling of the many working groups (with their core enterprise middleware foci).

**MACE-Dir (Directories)**
The MACE-Dir Working Group researches and develops architectures and common practices to facilitate intra- and inter-institutional information exchange about people and services stored in an enterprise directory.

**MACE-Shibboleth (Authentication and Authorization)**
The MACE-Shibboleth Working Group develops architectures and corresponding software to support intra- or inter-institutional authentication and authorization for access to restricted electronic resources.

**HEPKI-TAG (PKI)**
The Higher Education Public Key Infrastructure-Technical Activities Group (HEPKI-TAG) is a collaboration between the Internet2 Middleware Initiative and EDUCAUSE and was formed to investigate technical issues related to the deployment of PKI in higher education.

**MACE-WebISO (Authentication)**
The MACE-WebISO Working Group investigates "web initial sign-on" (WebISO) software, which leverages campus authentication services to allow users with standard web browsers to authenticate to web-based services across many web servers.

**VidMid (Directories and Authentication)**
Video Middleware (VidMid) furthers the development of middleware for videoconferencing and related areas and is a collaboration between Internet2 Middleware Initiative and the Video Development Initiative (ViDe). The working group focuses on resource discovery and authentication for point-to-point and multi-point videoconferencing, and similar middleware requirements for video-on-demand, data collaboration, and voice over IP.

Core Enterprise Middleware components enable "transparent use," providing consistent infrastructure for security, privacy and access to protected resources:

- Identity—unique markers of person, machine, service, or group
- Authentication—how you prove or establish your identity
- Authorization—what an identity is permitted to do
- Directories—where an identity's basic characteristics (attributes) are kept
- Public Key Infrastructure (PKI)—set of security technologies that relies on the exchange of electronic credentials called certificates

## NSF Middleware Initiative

The Internet2 Middleware Initiative also works in coordination with several other middleware-oriented efforts. The most important of these is the NSF Middleware Initiative (NMI) in which Internet2 partners with EDUCAUSE and the Southeastern Universities Research Association (SURA) under the consortium banner of NMI-EDIT. Funded with the GRIDS Center, these two teams work together on integrating campus and grid research infrastructures.

## To Learn More

Visit middleware.internet2.edu for information about working group activities, architectures, implementation practices and guidelines, software downloads, email lists, and software demonstrations.

Contact mw-info@internet2.edu with specific questions.

Some of these activities are supported by the National Science Foundation (NSF) under the NSF Middleware Initiative-NSF 02-028, Grant No. ANI-0123937.

200404-IS-MW

INTERNET2®

www.internet2.edu

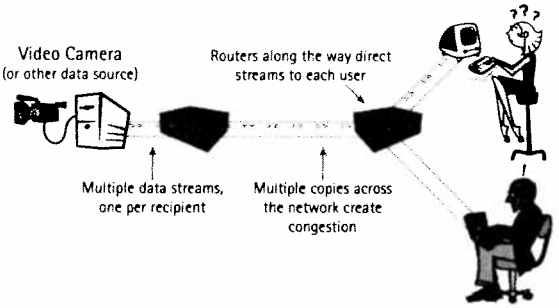
Internet2 members are developing and testing technologies that will give tomorrow's Internet the capabilities required by advanced network applications.

# Internet2 Multicast

*www.internet2.edu/multicast/*

Multicast is a set of technologies that enables efficient delivery of data to many locations on a network. In today's Internet, the dominant model of communication is "unicast"—the data source must create a separate copy of the data for each recipient. When there are many recipients, and when large amounts of data (e.g. streaming video) are being sent, unicast becomes prohibitively wasteful of bandwidth. The key idea behind multicast (right) is to create each recipient's copy of each message at a point as close to that recipient as possible, thus minimizing the bandwidth consumed.

## Unicast Streaming




## Multicast Streaming

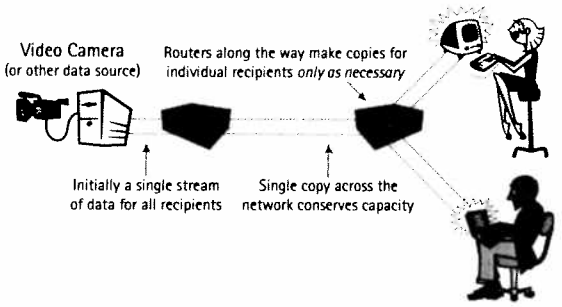



Photo courtesy of Argonne National Laboratory, Mathematics and Computer Science Division

Network multicast capability is crucial for distance learning, digital video libraries, online collaboration tools, and other types of advanced applications important to research and education. For this reason, Internet2 members are at the forefront of multicast deployment. The Internet2 backbone networks vBNS and Abilene, as well as many Internet2 regional and campus networks, have fully deployed multicast. Multicast is routinely used to distribute better-than-TV-quality video to thousands of viewers at Internet2 universities. The Access Grid enables the creation of a potentially globe-spanning virtual conference hall (left).

Internet2's non-commercial research and education networks have made the speedy deployment of multicast possible. Through the work of Internet2's industry partners and of standards bodies such as the Internet Engineering Task Force, the technologies being tested in the Internet2 multicast effort are now making their way into the global Internet.

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Internet2 science and engineering applications are at the forefront of research that spans many disciplines. Internet2 advanced networks have made it possible for scientists and researchers to share data from geographically distant locations in real-time at rates previously unachievable. These advanced network capabilities are facilitating global collaboration in fields as diverse as meteorology, high-energy physics, and earthquake engineering.

## Large Hadron Collider

CERN

*http://www.cern.ch*

The Large Hadron Collider (LHC) is a new particle accelerator that will be used by physicists to investigate the properties of matter. The instrument is currently under development at CERN, an Internet2 affiliate member located near Geneva, Switzerland. When operations begin in 2007, it will produce roughly 15 Petabytes (15 million Gigabytes) of data annually for scientists around the world to access and analyze. Internet2's advanced networks and Hybrid Optical and Packet Infrastructure (HOPI) are essential parts of the data storage and analysis infrastructure in the United States. The data from the LHC experiments will be distributed through a four-tiered model. After a primary backup and initial processing at CERN (Tier-0), data will be distributed to a series of Tier-1 centers with storage capacity for a large fraction of the data. These centers will make data available to Tier-2 centers—a number of which are Internet2 member universities—via advanced networks around the world. The computing facilities at these sites are able to store sufficient data and provide adequate computing power for specific analysis tasks. Individual scientists will access these facilities through Tier-3 computing resources, which can consist of university departments or individual PCs.

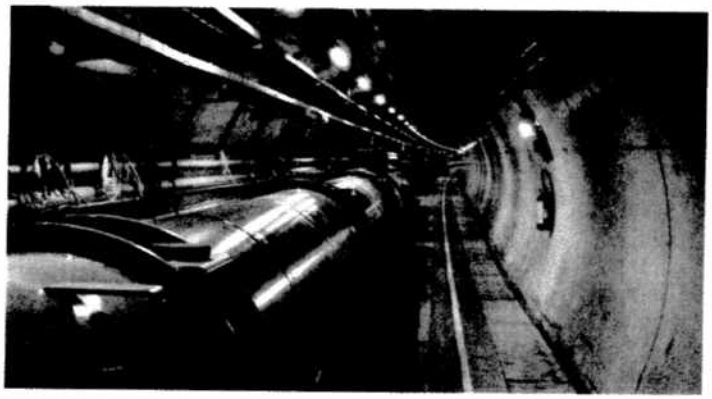

Image courtesy of CERN

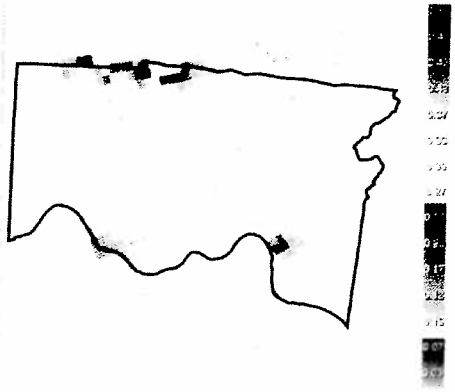

Image courtesy of Vieux & Associates, Inc.

## Integrated Robust Assured Data Services: High-Resolution Real-Time Weather Radar Data

UNIVERSITY OF OKLAHOMA

*https://www.radarservices.org*

The distribution of NEXRAD weather radar data via the Internet was pioneered at the University of Oklahoma in a project known as the Collaborative Radar Acquisition Field Test (CRAFT). CRAFT was the highly-successful prototype for the real-time transmission of meteorology data from multiple radars that led the National Weather Service (NWS) to adopt an Internet-based data transmission methodology. Integrated Robust Assured Data Services (IRADS) is an extension of Project CRAFT that is now distributing high-resolution NEXRAD Level II data from the network of over 140 Doppler radars operated nationwide by the National Weather Service. Data from each radar are transmitted to four NWS Regional Headquarters (RHQ) sites. Each RHQ server is linked to Internet2 advanced networks. From there, the data are transmitted directly to one of several top-tier sites, including the University of Oklahoma. Level II data provide the highest spatial and temporal resolution information available from ground-based atmospheric observations and are used for real time warning of weather hazards such as hurricanes and tornadoes; for initializing numerical weather prediction models; for verifying past events, such as the location of damaging hail; and for non-meteorological purposes, including bird migration studies, bird strike avoidance, and urban pollution transport.

## Network for Earthquake Engineering Simulation

INTERNET2 UNIVERSITY MEMBER NEES PARTICIPANTS

*http://www.nees.org*

Image courtesy of Rensselaer Polytechnic Institute (RPI)

Several Internet2 member universities are participants in the George E. Brown, Jr. Network for Earthquake Engineering Simulation (NEES). NEES, funded by the National Science Foundation to improve our understanding of earthquakes and their effects, includes 15 large-scale, experimental sites, which feature such advanced tools as shake tables, centrifuges, a tsunami wave basin, and field-testing equipment. Distributed across 10 states, these facilities are linked to a centralized data pool and earthquake simulation software. Data is shared between sites via the capabilities of Internet2's advanced networks, enabling the formation of a national virtual earthquake engineering laboratory. Together, these resources provide the means for collaboration and discovery in the form of more advanced research based on experimentation and computational simulations of the ways buildings, bridges, utility systems, coastal regions, and geomaterials perform during seismic events.

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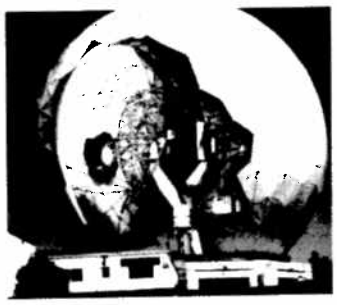

Image courtesy of MIT Haystack Observatory

## eVLBI

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

*http://web.haystack.mit.edu/e-vlbi*

Very Long Baseline Interferometry (VLBI) is one of the most powerful techniques for high-resolution imaging of distant radio sources in the universe and for making accurate measurements of the motion of the earth in space. Multiple radio telescopes scattered over the surface of the earth are used simultaneously in a powerful array to record continuous data at Gbps per telescope from a radio source, such as a distant quasar. VLBI has traditionally been done by physically shipping tapes or disk packs from the telescopes to a central correlator for processing. Internet2 and other advanced networks are now making electronic transmission of VLBI data, or "eVLBI," a reality on a global scale. The network-based eVLBI approach allows scientists to have immediate access to correlation results, even while experiments are in progress, which allows them to analyze the data immediately to make adjustments or changes in strategy to maximize the science output, or identify and fix problems at the telescopes. The eVLBI application is now able to link radio telescope facilities residing in Japan, Sweden, United Kingdom, the Netherlands, and the United States using advanced networks to stream simultaneous real-time observation data to a large correlator at the MIT Haystack Observatory outside Boston—essentially creating a virtual radio telescope with a diameter nearly the size of the Earth.

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## The National Ecological Observatory Network (NEON)

INTERNET2 UNIVERSITY MEMBER NEON PARTICIPANTS

*http://www.neoninc.org*

Image courtesy of the Environmental Sciences Division of Oak Ridge National Laboratory

Internet2 members are increasingly aware of the challenges and opportunities associated with a new generation of sensor networks that will change the way researchers investigate earthquakes, track ecological processes across continents, and explore the oceans by enabling them to discover previously unobservable phenomena through connection of the physical world to the Internet. One such project is NEON, a long-term continental-scale ecological observatory network designed to advance our understanding of how ecosystems and organisms respond to variations in climate and land use. The NSF-funded network will deploy standardized sensors and cyberinfrastructure across the United States to provide near real-time ecological data from 60 research sites to researchers, teachers and students. The San Diego Supercomputer Center and the Center for Embedded Networked Sensing, an NSF Science & Technology Center whose partners include Internet2 members USC, CalTech, UCLA, and several other UC campuses, are helping to design the network, using standardized sensors, field-deployed wireless communications, advanced cyberinfrastructure and Internet2 network connections, and a common set of data-collection protocols. In addition, formal and informal NEON education initiatives will help train the next generation of ecological scientists and offer web portals and modeling and visualization tools for citizens and students at all grade levels.

200604-IS-SE


www.internet2.edu

When you want to share secured online services or access restricted digital content, the Shibboleth system offers a powerful, scalable, and easy-to-use solution. It leverages campus identity and access management infrastructures to authenticate individuals and then sends information about them to the resource site, enabling the resource provider to make an informed authorization decision. Shibboleth software is at work today providing this capability—it's a powerful, secure, standards-based and user-friendly, interrealm access-control solution for research and education.

The Shibboleth system provides a standards-based link between existing campus authentication systems and resource providers of all kinds. For example, when a student requests access to a protected video clip, her home organization (origin site) requests her to authenticate (if she has not done so already) and then passes on the information that she is enrolled in Biology 562 to the site housing the video. The provider (target site) uses the fact that she is enrolled in this course to determine her eligibility to access the video.

Middleware components enable "transparent use," providing consistent infrastructure for security, privacy and access to protected resources:

- Identity—unique markers of person, machine, service, or group
- Authentication—how you prove or establish your identity
- Authorization—what an identity is permitted to do
- Directories—where an identity's basic characteristics (attributes) are kept

## The Shibboleth System Is a Solution for the Campus and the User

Because only information (attributes about the person requesting authentication) is exchanged, the Shibboleth system allows institutions with different technology architectures and security systems to easily collaborate without using proxies or managing thousands of external or transitory accounts. It also simplifies the process of integrating a service, such as access to a licensed library resource with campus-based authentication systems. The Shibboleth system can:

- Leverage existing infrastructure (once it's installed, other Shibboleth software-enabled sites can be easily added).
- Facilitate collaboration with other campuses, organizations, and off-campus vendor systems.
- Operate without releasing identity, where appropriate.

From anywhere in the world, users authenticate at their home campuses and those institutions pass information (attributes) on each user's behalf to the resource provider. Users don't need to remember multiple passwords for each restricted site to which they have access.

Below are typical scenarios that the Shibboleth system addresses:

- Enabling anonymous access (and thereby protecting personal privacy) by a member of the campus community to a licensed information resource available to "active members of the community."
- Ensuring anonymous access to a remote information resource where access is limited to "people associated with Course X at the origin site."
- Providing access to a restricted service using an attribute such as a person's name to determine authorization. For example, a team of researchers forming a multi-institutional workgroup can control the release of their attribute information to the workgroup site. In this scenario, access would be denied if an individual chose not to provide the required information.

## Who Is Using the Shibboleth System?

Internet2 and a group of leading campus middleware architects from Internet2 member schools and corporate partners constitute the project and implementation team for the Shibboleth initiative. Organizations collaborating in its development include national and international higher education institutions, their partners, content providers, and government agencies.

- At The Pennsylvania State University during fall semester of 2002, Information Technology Services and the Department of Physics piloted the Shibboleth system. Now in production for more than a year, the Shibboleth system has successfully enabled 1,200 Penn State students enrolled in three physics courses to access resources at North Carolina State University to complete their course assignments.

- The National Science Digital Library (NSDL), funded by the National Science Foundation, uses the Shibboleth system to facilitate seamless access for its patrons and community participants. David Millman, the director of Research and Development at Academic Information Systems at Columbia University and a member of the NSDL Core Integration Team said, "The NSDL has long been committed to the Shibboleth technology because of its scalable, distributed architecture and its privacy protections, both critical goals of the NSDL itself."

During 2003, twenty university campuses and higher education service providers, along with six digital content providers/publishers and three course management vendors/publishers, participated in the Shibboleth Pilot Project. Numerous campuses and higher education associations as well as content, service, and learning management system vendors are working on improvements and enhancements to the Shibboleth system.

"At Ohio State, we believe that the ability to provide trusted authentication across different organizations is an essential requirement for today's course management systems. We're working with other universities, as well as our library, to offer single sign-on capabilities to diverse and distributed student populations with the course management system as the front door to these integrated services."

*Steve Acker, Director of Learning Technologies Research and Innovation at The Ohio State University*

## Federations: Sharing Resources across Domains

When a number of organizations join together to use Shibboleth software to share access to resources in a common way, this is called a Federation. The Shibboleth system supports federations by providing scalable methods to manage and distribute configuration and security information among a large number of organizations, and a common vocabulary for user attributes. Internet2 is establishing federations in support of the needs of US Higher Education, and other federations are emerging in other communities.

## To Learn More

Visit shibboleth.internet2.edu for information about implementation requirements, software downloads, email lists, and software demonstrations. Contact shib-info@internet2.edu with specific questions.

The development of the Shibboleth software was supported in part by the National Science Foundation (NSF) under the NSF Middleware Initiative-NSF 02-028, Grant No. ANI-0123937.

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Internet2 advanced applications are helping instructors develop new teaching techniques, enhancing the learning experience for students, and extending universities beyond their geographical boundaries. By bringing together learning communities and removing barriers to information retrieval and learning resources—Internet2 applications are changing the way we learn and teach.



## Undergraduate Education

**Screenwriting Course**
Bradley University

*http://gcc.bradley.edu/slane/*

In order to be competitive in the entertainment industry job market, university graduates need to know how the industry works from top to bottom. But, how do you expose students to agents, writers, directors, and producers? And, how do you do it from Peoria, Illinois? Jeffrey Huberman, Dean of the Slane College of Communications and Fine Arts at Bradley University, explains, "We provide students with an excellent education in many aspects of the entertainment industry, but we didn't offer a course in screenwriting. We thought Internet2 advanced network technology could provide a solution." Huberman collaborated with California State University, Los Angeles (CSLA) to create a screenwriting course, which enrolled students at both Bradley and CSLA. The course included guest lectures by agents, screenwriters, and production executives—brought live to the classroom via interactive videoconferencing. Through the use of advanced networking technology, students learned all the steps involved in bringing a project to production from professionals who are successfully managing careers in Hollywood.

## Distance Learning

**Singapore-MIT Alliance**
Massachusetts Institute of Technology
National University of Singapore
Nanyang Technological University

*http://web.mit.edu/sma/*

The Singapore-MIT Alliance (SMA) is an advanced engineering degree program that combines an innovative distance-learning component with traditional on-campus learning. SMA is a highly-collaborative effort that provides thousands of students with courses using the most technologically-advanced distance learning facilities available. SMA course offerings use a live lecture format delivered via videoconferencing with supplemental data content provided over an application sharing link. Vijay Kumar, Assistant Provost & Director of Academic Computing at MIT, comments, "Our goal is to improve the educational experience and meet the lifelong learning needs of our students while simultaneously expanding MIT's reach and influence by providing educational offerings to a global audience."

**Integrated Seminar in Nursing Informatics**
Committee on Institutional Cooperation

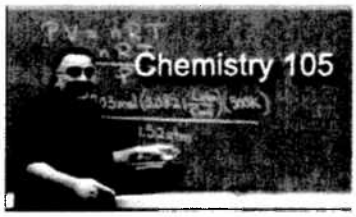
*http://www.cic.uiuc.edu/programs/CICCourseShare/*

The Committee on Institutional Cooperation (CIC), a consortium of 12 research universities, piloted a course in nursing informatics for four participating institutions: University of Iowa, University of Wisconsin-Madison, Indiana University, and University of Michigan. This innovative course used the Internet2 Commons H.323 Videoconferencing Service to deliver live, interactive lectures to students. The course was supplemented by an on-demand video archive and web-based conferencing and course management. The four participating universities used CIC's CourseShare administrative system, which allows students to register and pay tuition, receive grades and credit for specialized inter-institutional courses all at their home campuses. Connie Delaney, professor at the College of Nursing at the University of Iowa, stresses, "This collaboration provides creative strategies that leverage the scarcity of nursing informatics faculty and at the same time offers students participation in a wealth of research projects and innovations across multiple institutions."

## Collaboration Tools

**MediaVision and Chemistry 105**
Case Western Reserve University

*http://www.cwru.edu/its/itac/mediavision/*




MediaVision Courseware is an advanced instructional technology project that enhances existing teaching methods with new multimedia learning content. For Chemistry 105—a large, lecture-style undergrad chemistry course—MediaVision provides students with video recordings of lectures, review sessions, and homework assistance; MP3 audio recordings; and an on-line textbook. Lectures and review sessions are recorded; encoded for network distribution; indexed and "published" to the web where they can be keyword searched by students. Network-based delivery extends access to the multimedia materials both on and off campus, which is especially critical to commuting students. MediaVision Courseware illustrates how technology can improve the educational outcome as well. During the first semester of Chemistry 105 using the MediaVision Courseware, scores for the first two tests rose to an 81 average, from a previous average of 72.

**Digital Anatomy**
Stanford University
University of Wisconsin – La Crosse

*http://havnet.stanford.edu/*

When Stanford University medical students "dissect" an anatomical specimen, they zoom in, rotate it, dissect it, and even put it back together again. Remote Stereo Viewer (RSV) is an educational tool that allows medical educators and students to view 3D stereo anatomical interactive photographs on a workstation. Since an anatomical specimen can be viewed in various stages of dissection, the student can go back and forth between layers to better understand the complexity of the structure. The high-resolution 3D stereo images are stored on a server and then individually downloaded to a workstation on demand, requiring high-bandwidth transport at a minimum of 35 Mbps. RSV is used in a "virtual classroom" style setting that allows multiple, remote users to access digital anatomy datasets and collaboratively view and discuss a virtual dissection in real-time. Dr. Sakti Srivastava has been using this tool for over three years in the gross anatomy class at Stanford and comments, "When we conducted field trials to evaluate the usability and learning efficacy of the applications, we discovered that its simple, user-friendly interface and high quality images made it an attractive option for students. When RSV was used both as an introduction to a real dissection and as a refresher after the dissection had been completed, students self-rated themselves as having better learnt the concepts and details."

## Remote Instrumentation

**Remote Microscopy Course**
University of Michigan
Lehigh University

*http://emalwww.engin.umich.edu/*

A Scanning Electron Microscope (SEM) at the University of Michigan (UM) plays a key role in courses taught at Lehigh University. Each year, the Lehigh Microscopy School attracts over 100 engineers and scientists who receive instruction in a wide variety of microscope techniques using SEMs and other state-of-the-art instruments. One of these instruments is the Philips XL30FEG SEM located in the Electron Microbeam Analysis Laboratory (EMAL) at UM. The Philips line of SEMs was one of the first to be completely computer-controlled, as opposed to the knob and switch "interfaces" on older instruments. Extending its usability via remote-control to an Internet-wide audience resulted from the work of Dr. John Mansfield and collaborators. Mansfield, Manager of EMAL, explains, "Advanced networks provide the bandwidth and performance required to control the SEM in real-time from anywhere in the world. Remote access extends the use of this extremely costly resource for instructional and collaborative research purposes."